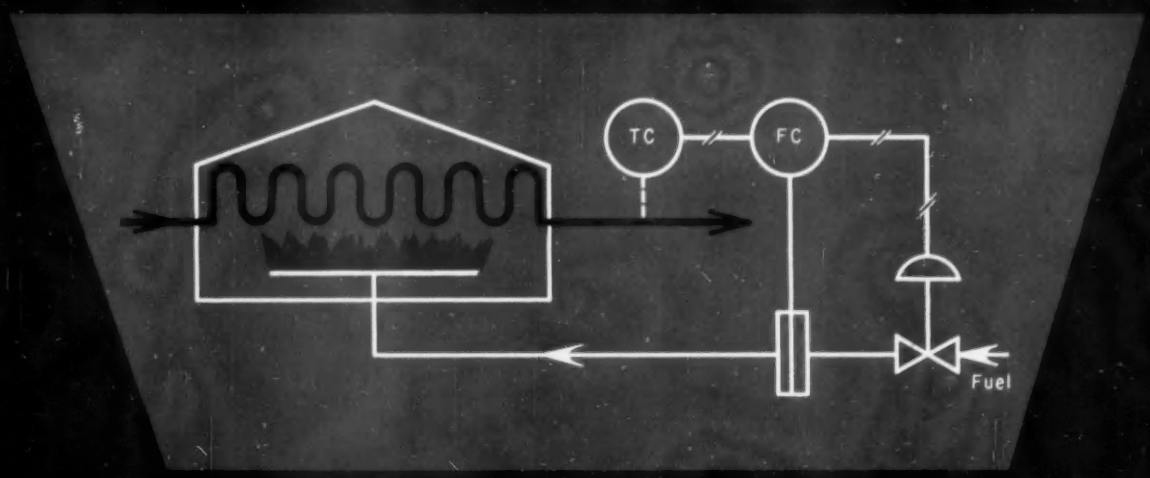
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

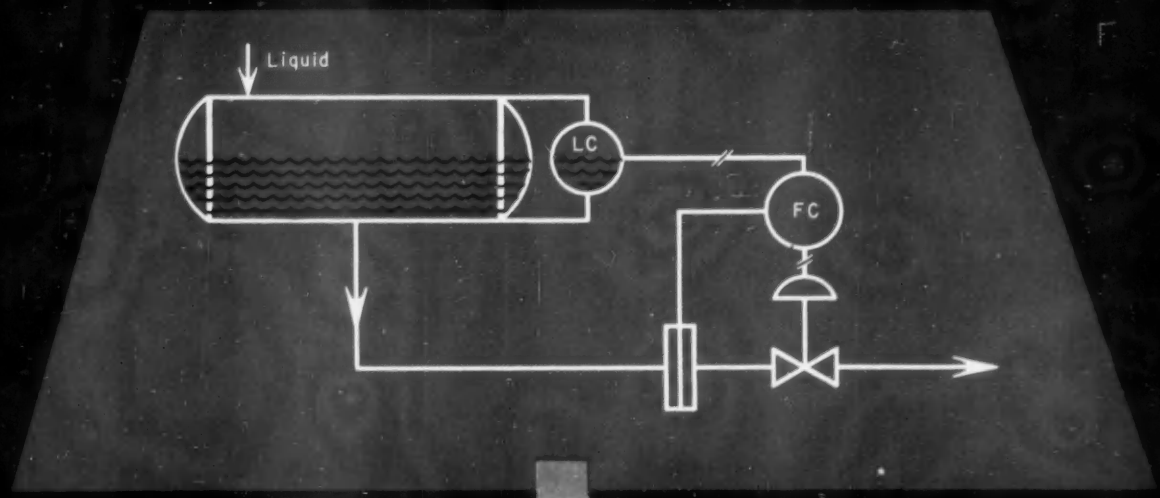
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PRICE 50 CENTS

MAY 1956



Direct or reverse actions in cascade control ?



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Design with Hybrid Amplifiers
Human Operator Dynamics
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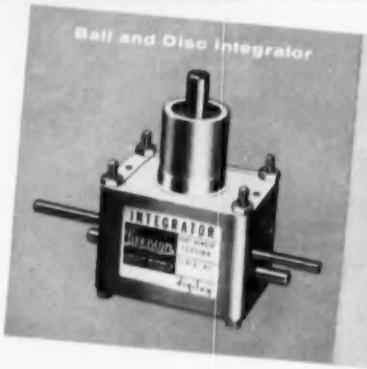


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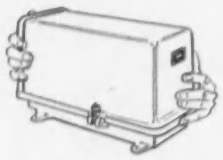
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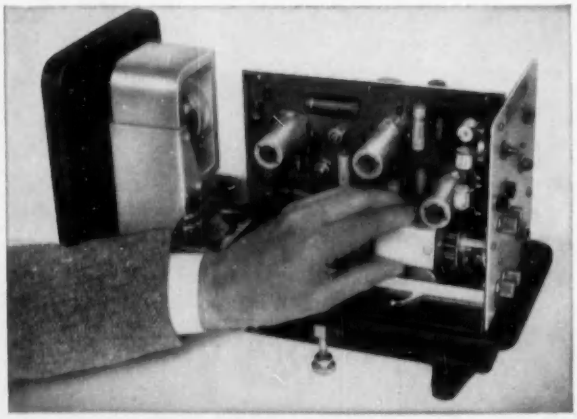
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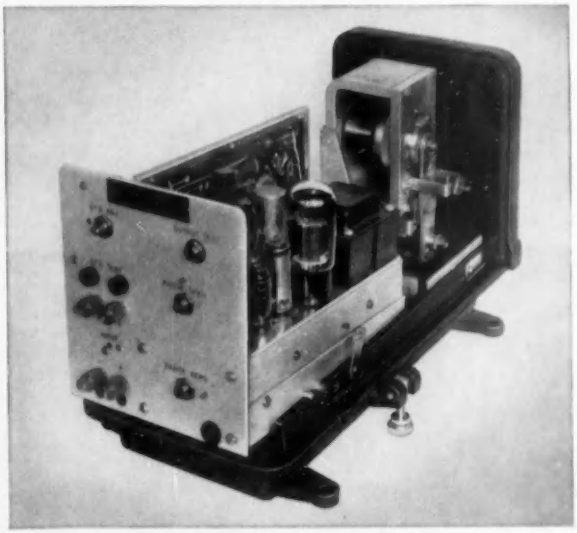
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Write for Bulletin **No. 98262.** Taylor Instrument Companies, Rochester, N. Y., and Toronto, Canada.

Taylor Instruments
MEAN ACCURACY FIRST

Control ENGINEERING

MAY 1956

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

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The Model MR-1 is a miniature airborne magnetic tape recorder manufactured by North American Instruments, Inc., 2420 N. Lake Ave., Altadena, California, and is described in their Bulletin 104.

* The formula "A53 + MR-1" demonstrates the ability of Statham Laboratories to cooperate with recorder manufacturers in a joint effort to serve the engineering field.

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SHOPTALK

BETTER BLOCKS IN OUR SYSTEM DIAGRAM

Our masthead boasts two changes this month. Byron Ledgerwood is now our Senior Associate Editor, and Harry Karp moves up to the Associate status. If a magazine operates like a control system, and editors like blocks in its diagram, then By could well fill the function of Power Source and Comparator. His vitality and fine ability to select and organize material has formed the backbone of our contents right from the start. Harry, who joined us a year ago, has been acting more and more like a Senser and Actuator in our diagram: he has displayed a powerful talent for searching out information and moving it into print. The changes will mean more time in the field for Harry, more time to concentrate on the programming and performance of our magazine for By.

GROUCHO ENCOUNTERS GRABBE

While in Chicago our editors (see below) made a point of gathering in front of a TV set at 7 p.m. to witness the Groucho Marx show. The reason: rumors that our West Coast consulting editor, Dr. Gene Grabbe, would be on the screen. The rumors were true. There stood Groucho and there stood Gene . . . and there, soon, lay the word "automation" all Marxed up. But Gene did his field credit. He not only gave Groucho and 20 million viewers a clear picture of automatic control, but came off—with an attractive female partner—a winner of the $2,000 jackpot.

ANALYSIS AT THE SOURCE

On March 15 the editorial staff packed its kits and took off for two days of round-the-table sessions with outstanding control organizations in the Chicago area. The picture, taken in the conference room of the Standard Oil of Indiana research building, shows part of the group that heard W. V. Cropper on the problems of developing instruments for analyzing products on the line. This kind of briefing—direct from the men who do the work—has made our reporting more realistic, and—we hope—useful.

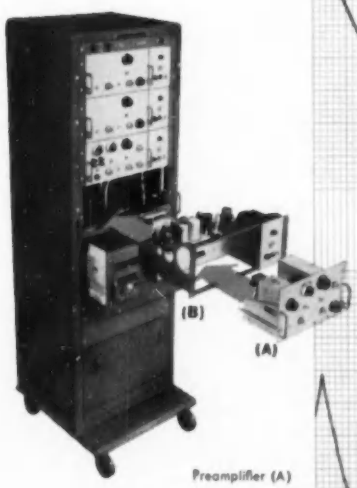


The listeners, l to r: G. Eckel, W. Garey, G. Brown, B. Ledgerwood—all CtE; C. Kenyon, S. Shields, J. Rhodes —all Stanolin; Editor Bill Vannah.

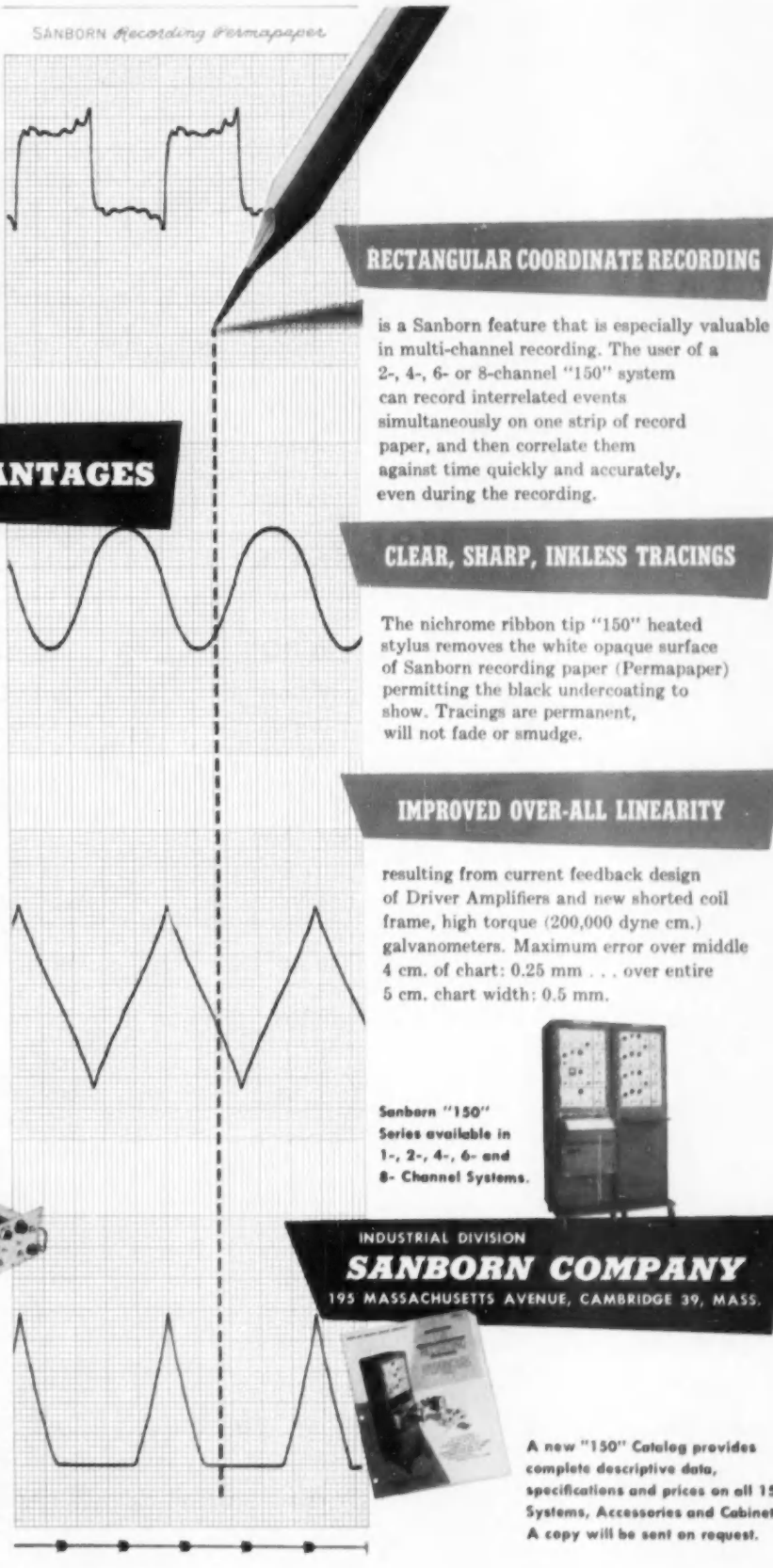
ALL SANBORN 150 SERIES OSCILLOGRAPHIC RECORDERS PROVIDE THESE

SPECIFIC ADVANTAGES

THE three foremost operating advantages of a Sanborn "150" are evident in the record, and are given at the right. Equally popular with industrial users is the *wide versatility* of these systems. Each one comprises a basic assembly to which the user adds his choice of an interchangeable, plug-in type preamplifier for each channel. Presently available different preamplifiers now number *eleven*.



Preamplifier (A) shown in position to plug into a Driver Amplifier with Power Supply (B) which are normally already in place in the Basic Cabinet Assembly



RECTANGULAR COORDINATE RECORDING

is a Sanborn feature that is especially valuable in multi-channel recording. The user of a 2-, 4-, 6- or 8-channel "150" system can record interrelated events simultaneously on one strip of record paper, and then correlate them against time quickly and accurately, even during the recording.

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...about Design Testing of Complete Systems

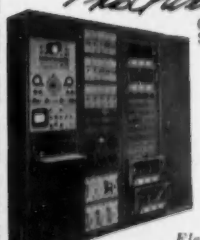
As a design, analysis, and test center, the Servomation® Building Blocks offer the design engineer equipment that features exceptional flexibility and ease of operation. Servo control systems can be quickly mocked-up and tested, with the wide variety of standard servo components, external patch cord and jackboard connections, and the versatile Servoboard® and Servoscope® components of the Building Blocks. Closed loop characteristics can be predicted and pre-production "bugs" eliminated. The Building Blocks also allow you to change design parameters in the mechanical part of the system simply by rearranging or substituting components.

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Tom Westover
Chief Control Systems Engineer



Electro-mechanical Control Systems and Components for Industry by

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Servo Corporation of America
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Please send me more information on Servomation® Building Blocks.

Name.....

Title.....

FEEDBACK

THE PROBLEM FORUM . . .

. . . this month features two responses to the challenge presented in March. The respondents will receive handsome engravings of Honest Abe. We offer similar works of art, or their equivalent, to contributors of other stimulating problems and ingenious solutions. With the ice breaking up in the lakes, control engineers need a few new fishing flies, or, perhaps, fuel for their outboards. Our pocket-sized portraits, signed by the Secretary of the Treasury, will come in handy for negotiations on that first fishing trip of the season. Join the forum . . . and good fishing.

Problem Digest

In a cigarette machine the transportation lag, T_t, L/S, $>> T_M$, the time constant of the variable speed drive motor, $> T_G$, the time constant of the nuclear gage that measures the basis weight of the completed cigarette rod. Design a feedback circuit for the control amplifier that precedes the variable-speed motor control.

Solutions

Two readers, *R. E. Murphy, Groton, Conn.*, and **A. Lange, Wayland, Mass.**, submitted solutions. Both apply disturbance-response feedback in such a way that the process machinery itself automatically adjusts a "plant model" of the process dynamics. Murphy's material is printed in light face and Lange's in bold face.

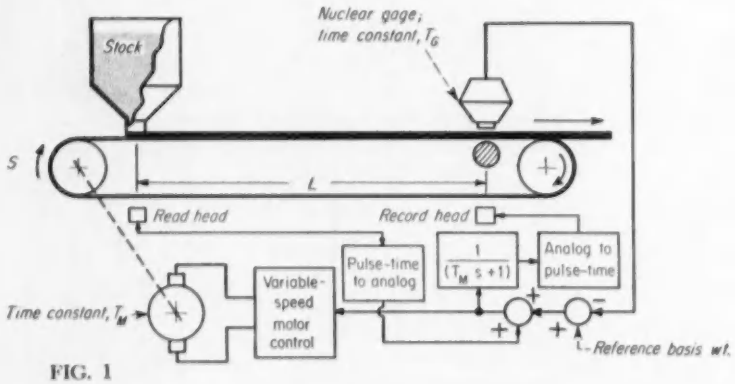


FIG. 1

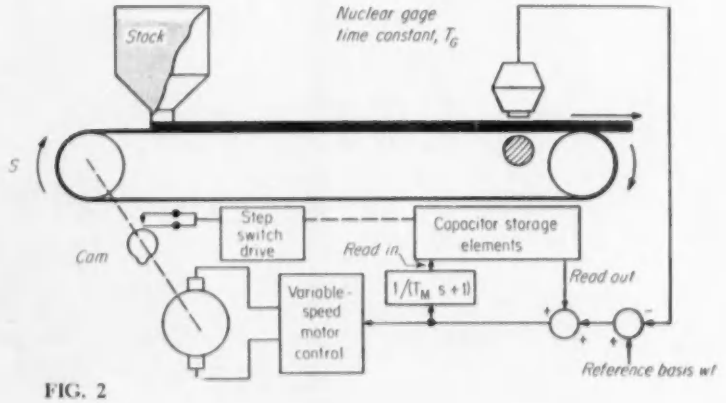


FIG. 2

Figure 1 shows the measured deviation from reference basis weight passing through an element with a single time constant equal to that of the drive motor. The output is then converted to pulse-time and recorded on a strip of magnetic material along the edge of the conveyor belt. At a distance L equal to the distance between the supply hopper and the nuclear gage, a head reads the pulse-time signal, which is then reconverted to an analog signal and fed back regeneratively. Note that the gain of the inner loop is one. Essentially, the disturbance-response feedback assembly has a "time storage" integral-plus-proportional action, storing the correcting information for a length of time equal to the machine's transportation lag.

This scheme utilizes the cause of the machine's transport lag to eliminate the transport lag. The machine creates its own correction signal, always synchronized with the fault that requires correction.

The magnetic material coated on the edge of the belt is similar to Minnesota Mining & Manufacturing Co. type RD 3010 Sprayable Magnetic Oxide Dispersion. Since the transfer function of a magnetic recording medium is a function of speed, and variable speed is a feature of the problem, the analog information is recorded with a speed-insensitive pulse-time modulation subsystem. Record and read heads (similar to Librascope type MH15a) are noncontacting. One head is movable for adjustment of the distance L.

Alternate methods are possible for delaying and storing the information:

► Figure 2 shows a contactor placed on the motor drive or on the belt rollers to periodically advance information samples stored in a step-switch capacitor device such as that used in a sampled-data controller. The drive mechanism determines the speed of the device.

► A motor contactor may also advance an electronic flip-flop capacitor-storage "bucket brigade" when the system speed is very high.

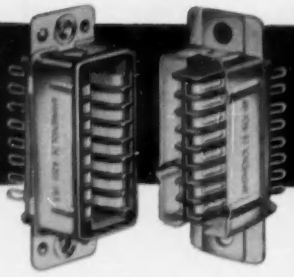
The system is essentially a speed-regulating device, whereas the true regulated variable is weight, or more exactly, weight per unit length. Therefore, the weight per unit length might be more directly regulated by manipulating the flow of material from the hopper, or by manipulating the mechanism which packs the tobacco.

More units, more money . . .

To the Editor—

The chart of computer characteris-





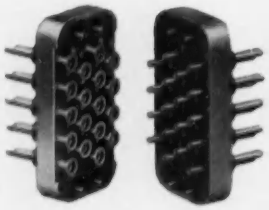
RACK & PANEL CONNECTORS

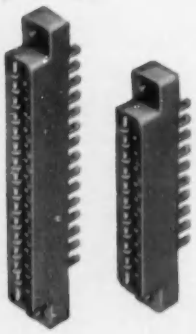
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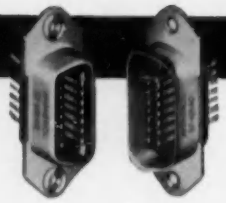
Ribbon, pin and socket, printed circuit contacts, standard and miniature sizes—only AMPHENOL provides *all* of the basic designs needed for rack and panel applications. That, for instance, is why it is almost impossible to find a major computer project in the United States that doesn't utilize reliable AMPHENOL rack and panel connectors.





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AMPHENOL

FEEDBACK

tics in the article "Comparing Large-Scale Calculators" by Messrs. Carr and Perlis in your February issue indicates that the IBM 702 is limited to ten tape units. My understanding is that this computer can be equipped with up to 100 such units.

Thomas E. McDonnell Jr.
Ford Motor Co.,
Dearborn, Mich.

. . . author says.

TO THE EDITOR—

The latest information on that machine is that it can be equipped with many more units than ten, although the basic computers, as listed with the monthly rental in my chart, had only ten units included in the cost.

Further, tape units beyond ten require the additional rental of matching apparatus. The chart was in error in that it did not list the 100 as top. But I think that it gave a reasonable picture, considering the lack of space for a detailed price analysis.

John W. Carr III
University of Michigan
Ann Arbor, Mich.

Less than greater

TO THE EDITOR—

I have read Mr. Kochenburger's excellent article on nonlinearity in control systems in the March issue of CONTROL ENGINEERING.

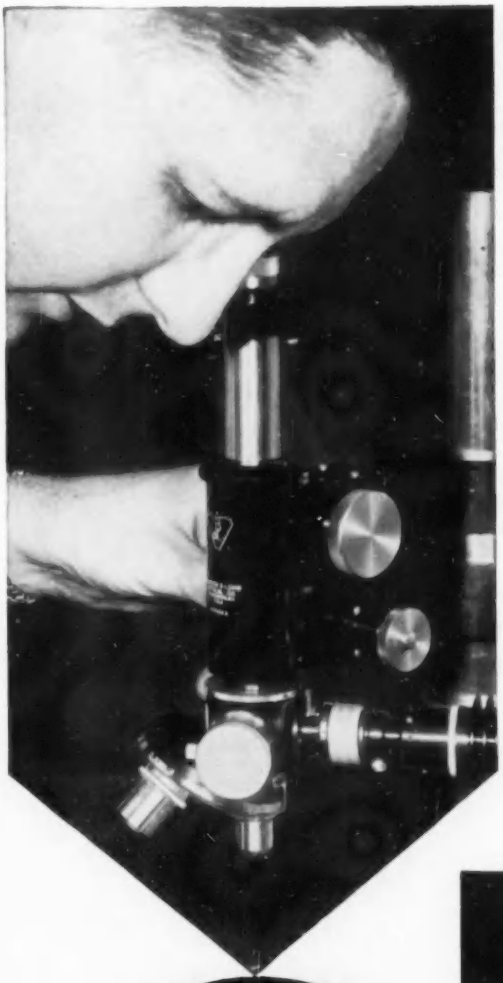
However, I have found the first paragraph on page 90 confusing in that the second and third sentences of the paragraph appear to be in contradiction to the first sentence. This contradiction arises due to the use of the word "stability" in these two sentences. If this word is "instability", the remainder of the discussion follows logically.

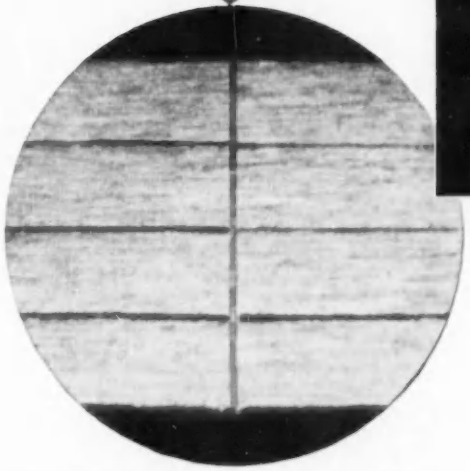
Jerome A. Joseph
Northrop Aircraft, Inc.,
Hawthorne, Calif.

Professor Kochenburger's original manuscript used "less than" symbols, those pfc's hash marks turned to leeward. We, in lubberly fashion, put them in facing windward. This creates the confusion—"stability" becomes "instability." Mr. Joseph is correct. We support his inversion. Ed.

Harvard-on-the-Charles

Several readers have requested information on Harvard University's graduate program in control systems engineering. We suggest that they write to the Dean of the Graduate School for a booklet about the program. Ed.





400X enlargement shows high precision gap and track construction.

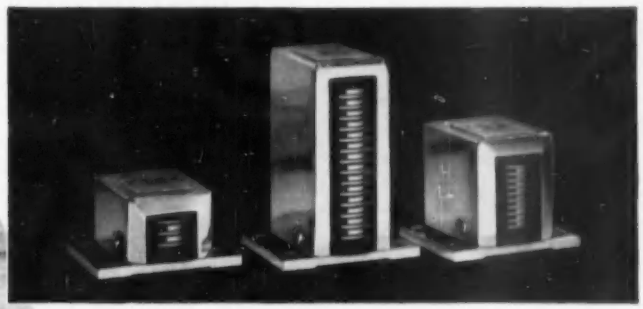
BRUSH *announces...*

NEW PRECISION MAGNETIC HEADS FOR CRITICAL RECORDING APPLICATIONS

Brush now offers a new design concept in multi-channel magnetic heads which provides extremely close tolerances to assure accuracy in recording and reproduction. These heads have already been proven in exacting airborne and missile applications.

ADVANTAGES

- **Uniform output assured by close mechanical tolerances on track width and channel spacing ... ± .002 in. maximum.**
- **Channel-to-channel timing accuracy provided by precise gap alignment... ± .0001 in. maximum.**
- **Crosstalk minimized by full shielding.**
- **Sustained accuracy under severe operating conditions assured by our new construction techniques.**



AVAILABILITY

Brush offers these heads in three designs: providing 7, 8, or 13 tracks per inch. Heads may be interlaced to provide up to 25 tracks per inch. Modifications or new designs using this construction technique may be made to your requirements. Consult Brush on your magnetic head needs—write Brush Electronics Company, Department N-5, 3405 Perkins Avenue, Cleveland 14, Ohio

BRUSH ELECTRONICS COMPANY

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BRUSH 6 ELECTRONICS

DIVISION OF CLEVITE CORPORATION



Denver manufacturing plant now under design

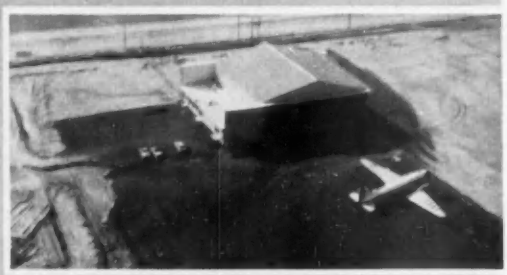


Infrared laboratory



Instrumentation laboratory

AIRBORNE ELECTRONICS AND WEAPON CONTROL SYSTEMS



Initial unit of flight test facility



Communications pilot line production



Simulators in computing center

At Ramo-Wooldridge today there exists a wide range of projects intended to aid aircraft in navigating to the vicinity of targets, finding the targets, destroying them, and returning safely to base. Work is under way in such fields as infrared and microwave detection, information display, communication and navigation, and analog and digital computing. Some projects are in the laboratory development stage, some in the flight test stage, some in pilot production.

Good progress is being made in the establishment of facilities and operational patterns that are well tailored to the unique requirements of advanced electronic systems work.

Positions are available for scientists and engineers in these fields of current activity:

Communications Systems
Digital Computers and Control Systems
Airborne Electronic and Control Systems
Electronic Instrumentation and Test Equipment
Guided Missile Research and Development
Automation and Data Processing
Basic Electronic and Aeronautical Research

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5730 ARBOR VITAE STREET, LOS ANGELES 45, CALIFORNIA

DONALD McL. FROTHINGHAM **tests thought in action**

"Tell us what you want to measure or control—and we'll do it with digits." These sweeping words, spoken with a Yankee drawl and wry, craggy smile, are Don Frothingham's credo. Are these the words of a boaster or a breezy generalizer? Hardly. Anyone knowing the man and his work recognizes the expression of a true New England pragmatist: one who constantly tests the truth of thought in action.

Don's windmill-tilting outlook had a proper Bostonian founding. Born at the turn of the century of Back-Bay parents, he earned his SB in EE from Harvard University in 1922. This course required two quarter-year stints in industry. The tall, spare young student spent one of them helping an electrical contractor wire up a New York skyscraper at 466 Lexington Ave. and the other elbow-deep in oily chips at General Electric's machine-shop school. Today, as chief engineer of Barnes Engineering's Binotrol Div., he reflects these apprenticeships in a unique ability to wed practical machine action with the esoteric antics of electrons.



Don, flanked by a Binotrol console, fondles a Mylar tape, on which he'll "program almost anything".

Variety breeds the control engineer

Frothingham is a colorful example of how many ingredients combine to produce a creative control engineer. After college he went to work with analytical and simulating techniques to sleuth the reasons for "noise" and distortion in telegraph signals. A few years later he met a kindred spirit in Dr. George De Bothegat—one of the world's foremost engineering mathematicians. De Bothegat had recently formed the Bothegat Impeller Co. to commercialize some of his advanced ideas in fan designs (which are still used today), and Don spent three rewarding years as his assistant.

In 1928 an uncle died and the young engineer rolled down his sleeves and took over the vacant desk in the New York Stock Exchange firm of Delafield and Frothingham. His steeping in earthbound mathematics proved invaluable during the next few desperate years on Wall Street. In 1931 the partnership decided to close up and was one of the rare ones to emerge "solid" from the panic. Don rolled up his sleeves again and took over as chief engineering authority of the Westport-Fairfield section of the newly-building Merritt Parkway in Connecticut. For four years he did "geometry and trigonometry all over future Exurbia". When the road was finally in, he joined IBM to develop some of its early systems for mechanized bookkeeping. And just before the war he put in an enjoyable year developing a basic patent in the controlled flow of extruded metal for an artillery shell manufacturer.

Wartime saw Don Frothingham managing engineering for McGuire Industries in Greenwich, Conn. His pioneer work in military electronics there and in the postwar Telemark Co., which he helped form, set the stage for the credo that grips him today. At Telemark he independently reasoned out the binary technique for using pulses in control ("How I wish your magazine had published its Digital Series then") and in '52 took his prototype for the Binotrol system to Olympic Development Co. in nearby Stamford. Last summer this company split off from its parent (Olympic Radio) and became Barnes Engineering; at the same time it announced the near-commercial version of Frothingham's climactic development (CtE, September '55, p. 22).

Today, between field demonstrations of his budding concept, Don relaxes as crew on a 6-meter racing sloop in Long Island Sound, or buzzes over that same water in a small plane. He started out with gliders in 1928 "to rise above the stock market" and not until 1950 did his innate sailor's distrust of "stinkpots" give way enough to let him apply for a pilot's license for power flight (seaplanes, naturally). "On the beach" in his Darien, Conn. home, the flying sailor becomes a woodturner and hi-fi disciple of Beethoven and Mozart—or rambles to a camp upstate for fishing and local square dancing.



The Foxboro M/58 Consotrol Controller (shown full size, without cover). Can be panel-mounted on Consotrol Control Station, or field-mounted.

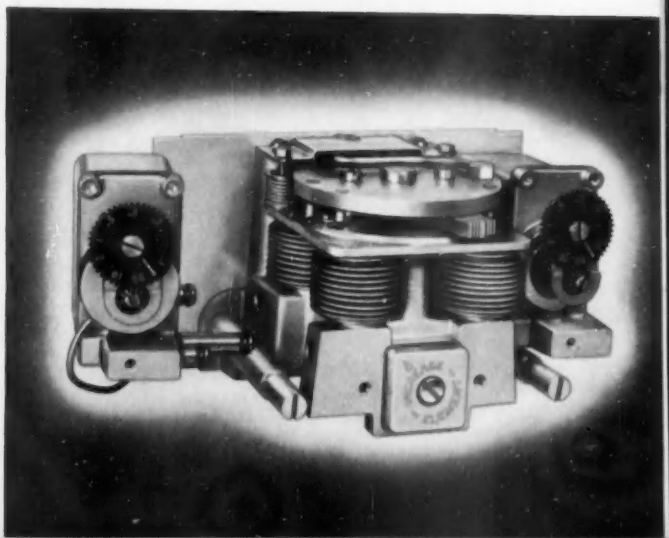
THE FOXBORO M/58 CONSOTROL

The M/58 Controller's Revolutionary Floating Disc System

Here's the exclusive Foxboro design development that gives M/58 Control its unique versatility, precision, and stability. The floating disc and matched bellows assure uniformly high controller sensitivity and pin-point control action, even at widest settings of the proportional band. Lever-set proportional band adjustment is calibrated to 500%.

Component Construction Gives Unrivaled Versatility

Not only is the complete controller easily detachable as a unit, but also, each component is a "plug-in" unit. For example, reset plugs in at right as shown; derivative, similarly, at left. All 4 control actions, with 2 reset ranges, are available and easily adjustable to widest variations in operating conditions. Proportional action from 1 to 500% quickly set by lever.



Outperforms all other controllers!

...the controller with the FLOATING DISC



If you think this claim is exaggerated, just put a Foxboro M/58 Consotrol* Controller on your process. The tougher the job, the more it will outperform other controllers! Or ask any present user . . . many of the largest, most progressive petroleum and chemical processors are using hundreds of these instruments. They will unhesitatingly confirm that this exclusive Foxoboro development has put their processes "on stream", automatically and smoothly from the control room, without false starts or confusion.

The M/58 Controller can do the same for your process. The flexibility of its control functions makes it readily adaptable to *all* processing techniques. All four actions are available, with two ranges of reset . . . all are easily adjustable to the most widely varying operating conditions. For example, reset and derivative functions plug in . . . proportional action from 1 to 500% can be quickly set by a lever. And calibration is a simple zero adjustment!

Get full details on this simple, truly "universal" Controller. Write for Bulletin 13-19 and ask your Foxboro Sales Engineer for a demonstration. **The Foxboro Company, 365 Norfolk St., Foxboro, Mass., U.S.A.**

*Reg. U.S. Pat. Off.

FOXBORO CONSOTROL INSTRUMENTS

Reg. U.S. Pat. Off.



Engineers popped from behind Starlight Root portieres to hear Dr. Joseph Kaplan launch the special evening session on the Satellite.

BIGGER, BOLDER, BROADER, MORE BEDAZZLING:

IRE Holds a Seam-Bursting Convention

Traditionally the Institute of Radio Engineers Annual Meeting is an electronics techniques and products convention. But in the most recent one—the 44th run of the world's biggest engineering get-together—this basic flavor seemed almost completely camouflaged with avid concern for other disciplines and fields by this young and aggressive society.

Take the control field. How many control engineers were among the 45,000 who came to New York during the week of March 19? The number must have been sizable. Certainly at least a dozen of the 55 sessions were heavily biased toward control technology. And a significant share of the products crammed into 714 booths at the Kingsbridge Armory and Palace was designed specifically for the automatic-control loop. Still more indicative: three cluttered "Positions Vacant" boards in the Waldorf lobby were dominated by calls for engineers with "feedback-systems" backgrounds (i.e., control engineers).

"Borderline" Engineering

The philosophy behind IRE's broad coverage was probably best described by John T. Henderson in an address at the annual banquet on "Borderline Engineers". The National Research Council of Canada scientist noted that the radio engineer deals with natural phenomena that recognize no boundary and suggested that "borderline engineers"—those laboring in an area where skill in an allied subject is as important as skill in engineering—will be the ones to extend the scope of radio engineering.

IRE departure from straight circuitry, components, and communications was especially marked in these "borderline" sessions:

- a six-man panel on the scope, launching, and instrumentation problems of Project Vanguard—the U. S. earth-satellite program
- two sessions on nuclear instrumentation, including papers on reactor control and control of a boiling-water power plant
- a session and panel on medical electronics, with the main accent on biological and physiological instrumentation
- three meetings on computers, the final a panel on economic, educational, and social problems posed by use of computers

Up in the Bronx the expanding technical interests of IRE were harder to spot in the 4½ acres of products, which ranged from small nameplates to massive digital computers. But after hours of trudging (we calculated a full day's walking would permit only 51 sec in each booth) the wary, weary control engineer could tick off these "borderline" trends:

- mechanical design infiltration—the obvious need to convert electronic signals into motion for control system application has led to more servo motors, gear trains, and related positioning hardware at this show
- Indication and recording—many devices to present useful information on variable measurements and system performance were evident; quite a few were analogous in scope and function to industrial instruments.
- use and performance—particularly in computers; much less stress on circuitry and components, more on problems-solving capabilities of complete systems and subsystems.

Aside from its broader scope, there was a new, more vibrant marketing climate this year. The searching control engineer found it easier to identify items of interest: booths had more emphasis on specific products, less on

WHAT'S NEW

A BUSY DAY WITH IRE

An engineer with only one day to spend in New York really had to step along to properly sample the big convention. The pictures hint at the pace he had to set from dawn to dusk.



1—A FREE BREAKFAST included a friendly briefing on the virtues of working for the company providing the victuals. This "Hospitality Room" was near the main registration desk.



2—INTO A SESSION for a quick exposure to the latest thoughts on Information Theory from the lips of its Prime Mover, Dr. Claude Shannon of Bell Telephone Labs.



3—OUT INTO THE LOBBY for a furtive scanning of the jam-packed job-offer notices. This year the salaries offered to experienced control engineers started at $7,000. Our man manfully resisted all siren calls.



4—ONTO A BUS for the hour-long ride up to the Bronx exhibits. Our man chatted en route with (r to l) CtE author J. M. L. Janssen, CtE Editor Bill Vannah, and Shell Oil's Dr. S. Kaufman.



5—TO ENTER THE ARMORY he had to trudge through the remains of 18 in. of snow—N.Y.'s second worst fall since the Blizzard of '88.

6—HOW HE TOURED THE BOOTHS IN FOUR HOURS



6—THE TOUR STARTED with a fleeting glimpse of booths, varying from fancy (Sperry Gyro, left) to classic (Honeywell).



THE PITCH: Inside the booths the talk was smart and to the point.



"What's the tape speed, Mac?"



"No, it can't simulate that!"



"Now this ratchet uses forwardlash."

THE WORKING DISPLAYS: Animated demonstrations and participation-type gadgets pulled the most onlookers. There were several "automated" machines for suppliers.



An Electronic Liberace



Solid, Solid-State Hi-Fi



An Electronic Walter Mitty

AND THERE WERE OTHER ATTRACTIONS, TOO . . .



"Oh gentlemen, you confuse li'l ole me."



"Be rectified—you can be sure if it's . . ."

kepco

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★ ***FAST*** RECOVERY TIME

★ ***GOOD*** STABILITY

★ ***LOW*** OUTPUT IMPEDANCE

KR Voltage Regulated Power Supplies are conservatively rated and are designed for continuous duty at 50°C ambient.

REGULATION: Less than 0.2 volts for line fluctuation from 105-125 volts and less than 0.2 volts for load variation from 0 to maximum current.

RIPPLE: Less than 3 mv. rms.

STABILITY: The output voltage variation is less than the regulation specification for a period of 8 hours.

RECOVERY TIME: Less than 50 microseconds. The excursion in the output voltage during the recovery period is less than the regulation specification.

OUTPUT IMPEDANCE: Less than 0.1 ohms from 20 cycles to 100KC. Less than 0.5 ohms from DC to 20 cycles. Many units have very much lower output impedance.



KR-3M

KR-16MC

FEATURES:

- Fast Recovery Time, Suitable for Square Wave Pulsed Loading.
- Voltage Range continuously variable without Switching.
- Either Positive or Negative may be Grounded.
- Oil Filled Condensers.
- Wire Harness and Resistor Board Construction.
- Power Requirements 105-125 volts, 50-60 cycles.
- Terminations on rear of unit.
- Locking type voltage control AC, DC Switches, Fuses, and Pilot Lights.
- Color Grey Hammertone.
- Guarantee One Year.

All models available for 400 cycle operation on special order.

1.5 Amp. KR SERIES

Model	Volts	6.3V AC	Rack Mount W	H	D	Price
KR16	0-150	Each supply	19"	12¼"	17"	$625
KR17	100-200	has two	19"	12¼"	17"	$625
KR18	195-325	15 Amp.	19"	12¼"	17"	$695
KR19	295-450	outputs	19"	12¼"	17"	$695

600 ma. KR SERIES

Model	Volts	6.3V AC	Rack Mount W	H	D	Price
KR 8	0-150	Each supply	19"	10½"	13"	$330
KR 5	100-200	has two	19"	10½"	13"	$240
KR 6	195-325	10 Amp.	19"	10½"	13"	$240
KR 7	295-450	outputs	19"	10½"	13"	$250

300 ma. KR SERIES

Model	Volts	6.3V AC	Rack Mount W	H	D	Price
KR 12	0-150	Each supply	19"	7"	11"	$270
KR 3	100-200	has two	19"	7"	11"	$180
KR 4	195-325	5 Amp.	19"	7"	11"	$180
KR 10	295-450	outputs	19"	7"	11"	$190

125 ma. KR SERIES

Model	Volts	6.3V AC	Rack Mount W	H	D	Price
KR 11	0-150	Each supply	19"	7"	11"	$180
KR 1	100-200	has one	19"	7"	7½"	$ 90
KR 2	195-325	3 Amp.	19"	7"	7½"	$ 90
KR 9	295-450	output	19"	7"	7½"	$ 97

To include 3" Current and Voltage Meters, Add M to Model number (e.g. KR 16 M) and Add $30.00 to the Price.
To include Dust Cover and Handles for Table Mounting, Add C to Model number (e.g. KR16 C) and Add $10.00 to the Price.
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- HIGH SENSITIVITY . . . from an all-metal, low-inertia movement.
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IT MATCHES . . . available with matching standard back or front flange SUPERGAUGE case design.

Ask for bulletins on Test Gauges . . . the Fig. 1404 above supplied in 4½", 6" and 8½" dial sizes, or, companion test gauges from 3" portable to 16" laboratory units.

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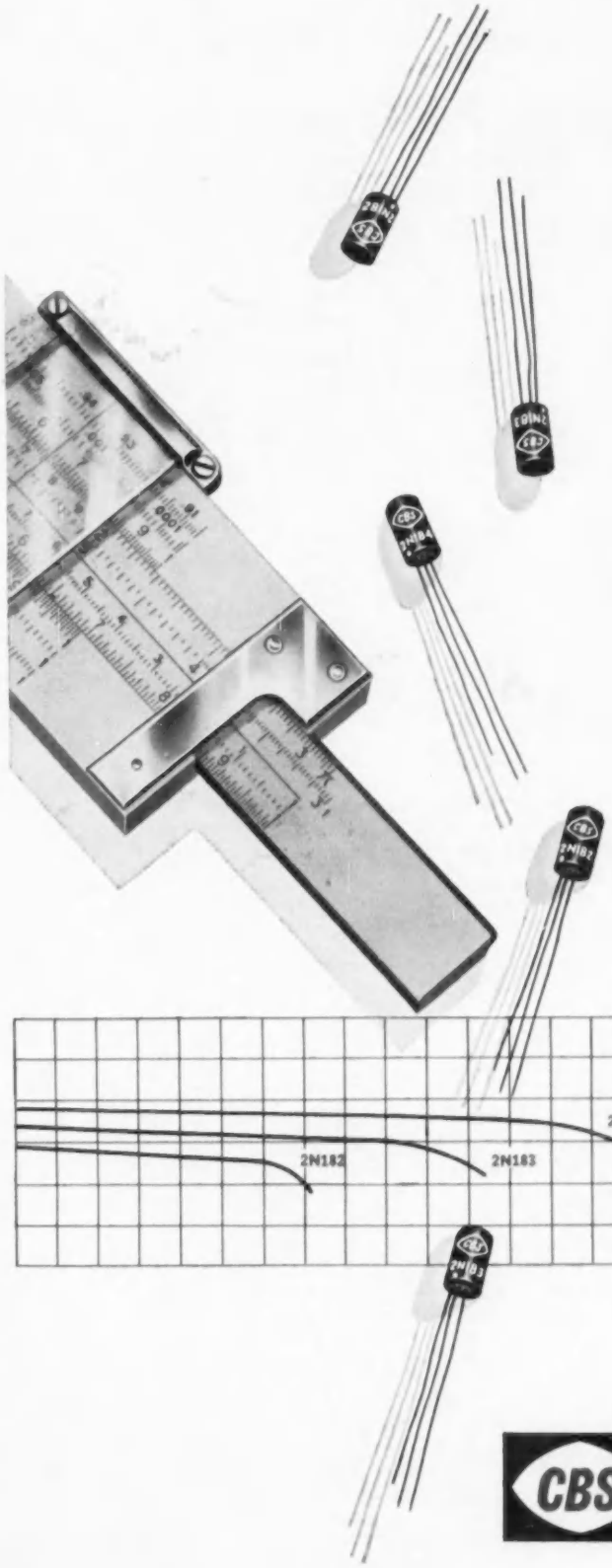
Division of American Machine and Metals, Inc., Sellersville, Pa.

company lines. Further, he could learn more, faster: booth attendants were better primed this year, seemed to know more about their products. It was obvious that most manufacturers–more than 400 of the exhibiters were small firms–are now in a period of "hard selling" to escape the attrition that could come from giant competitors.

Sessions Stimulate and Subdue

Reports from CtE editors covering the technical sessions contained both negative and positive feedback. One man, coping with the papers on "Automatic Control" and "Nuclear Instrumentation" on Tuesday, March 20, says he was either "in too deep, or high on the frothy surface". "A paper on nonlinear control," he advises, "was so theoretical it would have been infinitely better off in a IRD or AIEE Feedback Controls Committee session. The audience showed little interest in this and similar papers, but came abruptly to life when the topics involved circuits and components. For example, one talk on transistor selection and application in a nuclear control device brought forth eager questions on power voltage, current, frequency cutoff, pulse time, etc." This editor fears that poor presentation of control material at this session might have "scared off" engineers who were thinking of entering our field.

More optimistic thoughts came from the man who attended the symposium on the "Application of Recent Network Ideas to Feedback System Problems". "I like my routine physical check-up," he reports, "I needed and was happy to get this refresher in the analytical techniques of my field." He praises session-planner John Ragazzini: "The symposium thoroughly matched the know-how of the audience. The papers by Truxal and Aseltine were excellent reviews of the technology and of the tools for analysis and synthesis of systems. And the two papers by Bower and Graham got right down to specific means for handling certain classes of problems. Aseltine gave a particularly lucid treatment of root locus methods, emphasizing their geometric simplicity and appeal to the engineers' intuition. Bower's paper, which dealt with means of transforming various weighting functions to frequency and time scales, was also a unique contribution to control-systems-engineering literature –and should be studied particularly by those engineers working on mass



new CBS high-frequency transistors

NPN SYMMETRICAL ALLOY-JUNCTION

Alpha Cutoff Frequencies

2N182	2.5 to 5 mc
2N183	5 to 10 mc
2N184	10 to 20 mc

The basic design of these new CBS medium-power high-frequency transistors is: 1. *NPN symmetrical*...for better frequency response and reversible collector and emitter, permitting unusual applications. 2. *Alloy-junction*... for greater uniformity, high voltage and current, flatter gain characteristics, more stable and dependable performance.

The CBS 2N182, 2N183, and 2N184 are especially useful in radio-frequency...high-speed switching... and high-fidelity audio applications. Note the many desirable features. Write for Bulletin E-268 giving complete data and helpful application notes.

CHECK THESE FEATURES

1. High frequency response ... up to 20 mc.
2. High operating voltage ... up to 30 volts.
3. High power gain at 455 kc ... 35 db.
4. High dissipation rating ... 100 mw.
5. Low leakage current ... 3 μamps av.
6. Low base resistance ... 150 ohms av.
7. Low collector capacitance ... 10 $\mu\mu$f.

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through Advanced-Engineering.

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A DIVISION OF COLUMBIA BROADCASTING SYSTEM, INC.

Have You Considered CROSSBAR SWITCHES?

Whether it's the design for tomorrow's new computer—or for automatic process or production equipment, or a telecasting or radar control system, or any one of countless other situations calling for fast and reliable multiple circuit selection—you'll want to know and consider Cunningham Crossbar Switches.

FROM MANY SOURCES TO A SINGLE DESTINATION

Where electrical information originating from many points is to be measured or analyzed at a single destination, quick and reliable circuit selection is provided by the new Cunningham Type "F" Crossbar Switch.



OR TO SEVERAL...



The same multi-source electrical signals may, in addition to single point reading, be relayed to many other points simultaneously. The Cunningham Type "A" Crossbar permits each of a group of 10 circuits to be set up to one or more circuits of another group of 10.

THE Cunningham CROSSBAR



is a new concept of switching, doing the work of many relays without costly, bulky, multiple wiring—with greater capacity, speed and efficiency. Its electrical characteristics fully qualify it for today's most demanding multi-selection switching applications. For example, the Type "F" switch is used in test stands where hundreds of remote thermocouple readings can be taken from a single dial. It serves the petroleum industry with central station readings taken on temperature, pressures and liquid level at hundreds of remote points. Perhaps it can solve your problem with equal facility. And when this multi-source information must be supplied to more than one destination simultaneously, the Type "A" Crossbar can provide the answer. Check these features:

- HIGH FREQUENCY—switches over 35 mc
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WHAT'S NEW



INFORMATION THEORY session was astonishingly well attended. At the moment the picture was snapped, bearded Warren McCulloch of MIT was talking about signals in the human nervous system. Other speakers (l to r): Elias (MIT), Shannon (Bell Tel.), Goldman (Syracuse), Palmer (Sperry Gyro.).



COMPUTER SYMPOSIUM was led off by Dr. A. V. Astin of National Bureau of Standards. The panel of speakers (l to r): Forrester (MIT), Mauchly (Sperry Rand), Bonn (Sperry Rand), Astin, Sayre (IBM), Meagher (U. of Ill.), Jacobson (Wayne U.), and Cohen (National Science Foundation).

transport and heat-exchange control problems." Our reporter closes by advising readers to review these papers when the IRE proceedings are published.

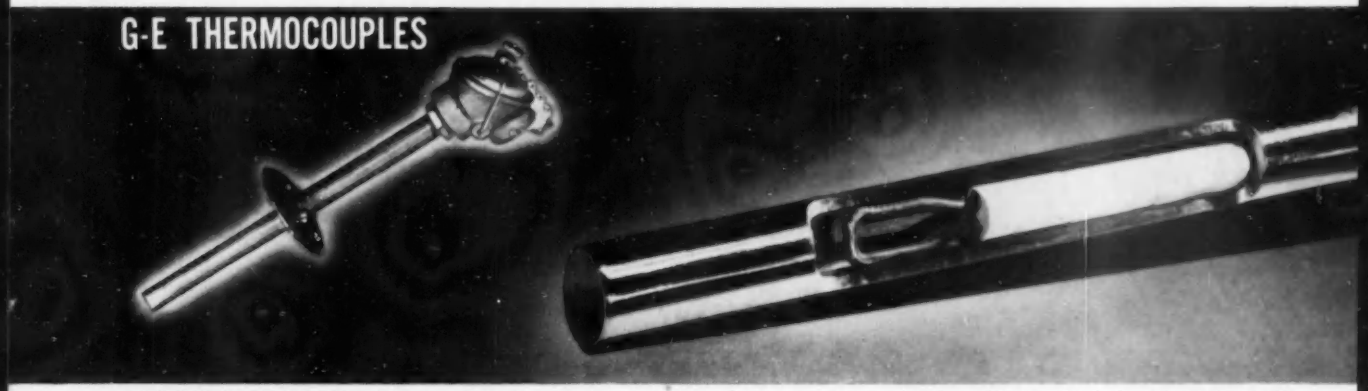
Some Info on Info Theory

Another CtE staff member joined an amazing 800 who gathered in the Waldorf's Grand Ballroom to hear a series of papers by Goldman, Shannon, and McCulloch on information theory. "The session seemed conscious of the 'newness' of its topic—about seven years old—and must have been attended mainly by people interested in its scientific vanguard rather than practical application (but 800 people?). Nevertheless, perhaps to refute the oft-heard comment that info theory is interesting but without much utility, Goldman's paper got down to figures for a specific situation: radio transmission using tropospheric reflection and the loss of message coherence due to different distances traveled by reflected waves. This loss of definition of the signal was slated as a coherence factor to show that it is possible to calculate the optimum distance for practical transmission by this technique using the modified Shannon theory. Then, Shannon himself—the man who sparked the whole movement—gave the outline for a technique to calculate the optimum word length for noisy channels (it was not particularly startling).

"At this point a session commentary conducted by Peter Elias produced only light questions—perhaps because both preceding papers appeared to be relatively straightforward, although they were quite complex mathematically. The closing paper by McCulloch indicated a new degree of agreement between information theory and results of the experiments he has been conducting in measuring neural impulses in the central nervous system." Our reporter thought this sobering note was in order: "The topic is loaded with an air of 'super theory' which doubtlessly attracts many of its

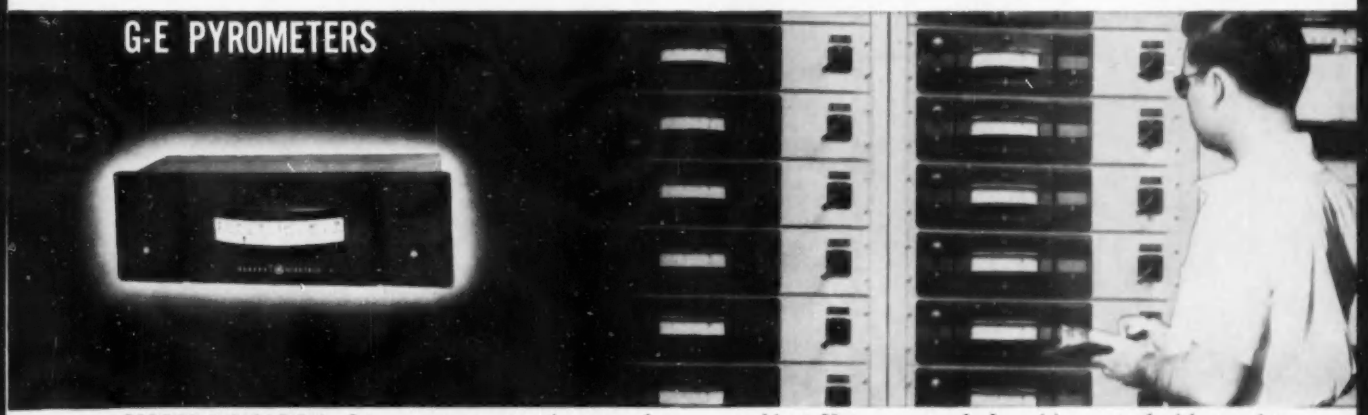
Now Get Precise Heat Process Control

G-E THERMOCOUPLES



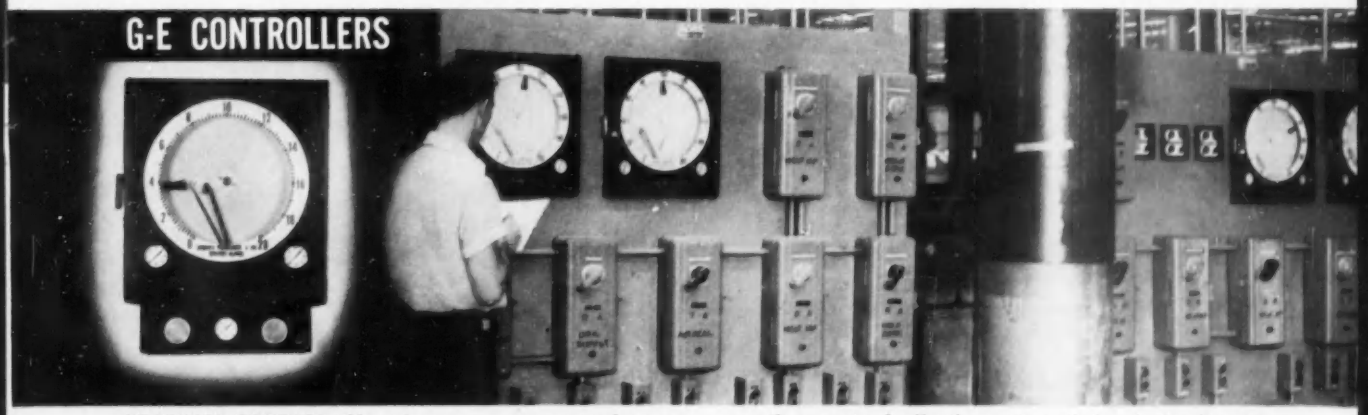
DEPENDABLE DETECTION of heat process temperatures can help you avoid costly production losses. General Electric's complete line of thermocouples, wire and accessories includes custom-tailored primary detection elements for nearly every heat process application. Butt-welded junctions in G-E thermocouples (shown above) respond faster to temperature changes than conventional twisted types. General Electric offers fast shipment of thermocouple wire from factory stocks.

G-E PYROMETERS



PRECISE INDICATION of temperatures can give you close quality control of products in your heat processes. G-E indicating and controlling pyrometers offer a low-cost way to maintain precise temperatures despite changes in voltage or ambient. You are assured of precision control with complete repeatability, and high sensitivity that initiates control action when temperature changes equal as little as 1/10 of 1% of full scale. Seven-inch non-parallax scales are easy to read.

G-E CONTROLLERS



RECORDED CONTROL of heat in your processes can give you truly continuous product quality. G-E potentiometric recorder controllers provide long-term accuracy, precise measurement and continuous dependable control. Features are continuous standardization, automatic break-circuit arrangement, and reduced maintenance by elimination of slidewire and batteries. Both pneumatic and electric control models are available for your individual applications.

FOR FURTHER INFORMATION on G-E thermocouples, pyrometers, and potentiometric recorder-controllers, contact your nearest G-E Apparatus Sales Office or write Section 587-5, General Electric Company, Schenectady 5, N. Y.

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Rated at 40 milliwatts (20 mw. minimum)

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Single stud, 6-32 x 5/16" or insulated base

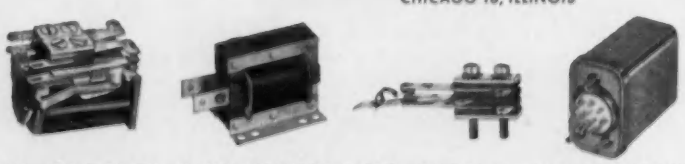
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followers—but thus far there has been no fair appraisal of its hardware significance today and in the near future."

The Impact of Computers

A complete change of pace was wrought by the symposium on "The Impact of Computers on Science and Society". "Technical jargon was notoriously absent," our man notes, "and most of the speakers confined themselves to intelligent but completely general and vaguely familiar statements about the subject. Sayre made a thoughtful point when he said that the ceiling on computers will not be a technical one—we are over that bridge now—but one of economics and social acceptance. Further, he stated that computers will be used less and less as mathematical computing devices and more and more as general logical devices in solving problems. Forrester aroused controversy when he questioned today's so-called urgent need for engineers. According to living-index figures, he said, engineers are far behind construction workers and manufacturing people. If engineers were really in demand the wage scale would show it. He went on to say that it is a misconception to believe that only engineers can program a computer and suggested that computer training might well start in tomorrow's high school or grade school." Our observer concludes, "The emphasis of the session was on practical problems rather than blue sky—but the sky showed through—in a practical way."

Solid-State Status

On the last day a special session reviewed some of the year's progress in the most-talked-about items in the IRE kit: solid-state devices. Seven papers originating from leading laboratories in the field (GE, Bell Telephone, RCA, Texas Instrument) reviewed such items as "Electrets", and h-f germanium tetrode, power transistors, and a semiconductor capacitance amplifier. Our peripatetic editor describes the paper on "Electrets" (a GE development, similar to ferroelectrics, but retaining a relatively permanent field after charging—5 to 20 years instead of weeks) as intriguing, but the final impression created was that they offer little advantage over present devices in producing polarizing fields. The paper, "Power Transistor Design Limitations", by Mason Clark of Bell Telephone, seemed a real contribution, although

FOR 3000 PSI PNEUMATIC SYSTEMS

SOLENOID VALVES
REGULATORS
INTERLOCK VALVES

Stratos' Western Branch now is turning out solenoid valves and pressure regulators for 3000 psi pneumatic systems. Light, reliable, precision-built, they complement the large group of Stratos pneumatic equipment for aircraft.



Model 7008 solenoid valve assembly

Exploded view of Model 7006 solenoid valve core, assembly and body

Model 7009 solenoid valve core

Photos not to scale

Solenoid valves are made in two types, each produced as: normally closed, normally open, and normally closed with manual override. Designed for continuous duty in aircraft pneumatic systems, Stratos 3000 psi solenoid valves are compact, light, and simple to install. Drawing less than 1 amp, they are fast acting (0.020 sec.) and their reliable performance remains unaffected by temperatures of −65°F to over 165°F.

Flow capacities are equivalent to a 0.040″ sharp edge orifice for the direct-operated size and to 0.312″ for the larger air relay type. The solenoid of the smaller model is used in the higher-flow air relay unit.

Both types are available as either complete units—or as core and seat assemblies which can be threaded into housings integral with the mechanism to be controlled.

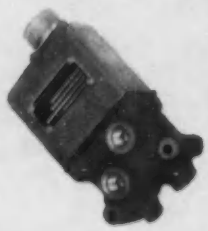


Model 7002 pressure regulator

Pneumatic Pressure Regulators by Stratos provide a wide range of adjustable downstream pressures and are designed to operate with 3000 psi supply.

The high flow model, with a flow capacity equivalent to a .115 diameter sharp edge orifice, can be adjusted to downstream pressures from 400 to 1500 psi. Downstream proof on this pilot operated unit is 5000 psi.

The poppet-type, medium flow regulator illustrated delivers a capacity equivalent to a .035 diameter sharp edge orifice, adjustable downstream pressures range from 100 to 800 psi., proof pressure is 1500 psi.



INTERLOCK VALVE
pneumatic/electric

Pressure:
Rated 400 to 1500 psi.
Proof 3000 psi.
Burst 4000 psi.

Control: Mechanical. Interlock switch rating at 30 V dc or 250 V ac is 10 amps.

Weight: 1.2 pounds

Ambient temperature range: −60°F to 165°F.

Provides pneumatic and electrical interlock to prevent premature energization of devices in series with actuator of interlock valve.

For more complete data on Stratos' 3000 psi solenoid valves and pressure regulators, write to: Stratos' Western Branch: 1800 Rosecrans Avenue, Manhattan Beach, California

Stratos Western Branch also makes:

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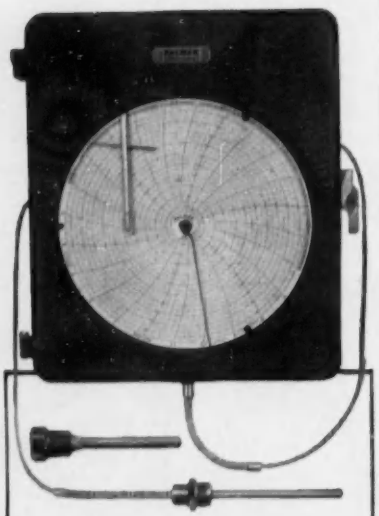
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the author talked his subject down. It suggested certain "figures of merit" for comparing power transistors for various applications—with optimized design for the transistors a distinct possibility. Conclusion: "This session would have been much better if more attention had been paid to 1) possibilities for applying the devices, and 2) comparing the new units with presently available devices. This more practical approach would not have detracted from the research and development approach that was taken, and certainly would have enhanced it."

Feedback for the Future

While these comments reflect the traditional error-correcting viewpoint of the control engineer, they are not intended to minimize this important point: by and large, this latest IRE meeting was a great and significant one. In its technical sessions and on its exhibit floor it tried to be all things to all men—and it darn near succeeded. But there is always a seam-bursting limit for something that keeps growing bigger each year. Perhaps the time has come for its directors to measure IRE for a new and better-fitting convention suit.

IRD-ASME Converge on Nonlinear Control

Continuing its annual conferences at university campuses, the Instruments and Regulators Div. of ASME held the second in the series jointly with AIEE at Princeton University, March 26-28. Nonlinear control systems was the theme. Northwestern University will host the third IRD conference early in April, 1957. There the papers will deal with control of physical systems in the presence of random disturbances.

C. A. Ludeke, University of Cincinnati, began the Princeton conference by demonstrating nonlinear phenomena visually and audibly with chalktalk, slides, moving pictures, and working models. Assemblies of springs, eccentric weights, sticky bearings, a belt sander, and surplus motors ranging from two horsepower to "Erector set" size whirred, scraped, ground, and thumped out the principles. He developed odd-order subharmonics that occur in second-order systems with exponential restoring effects and then demonstrated frequency entrainment.

At its dinner the evening of March 27 the division awarded honors to J. B. Reswick and T. Goodman for their paper, "Determination of System Characteristics from Normal Operating Records", presented at the first IRD conference, April 25-26, '55, Ann Arbor, Mich. W. G. Brombacher, past chairman of the division's executive committee, was honored for his work in standardizing and classifying measuring instruments and their literature sources.



VISITING GERMAN INDUSTRIALISTS got a thorough briefing on U.S. progress in automatic control from CtE Editor Bill Vannah on March 20. Sponsored by American Management Association, the visitors seemed well primed technically and asked many pertinent questions—particularly about digitally controlled machine tools. On Bill's left is the articulate young lady who provided simultaneous translation.

Saved in 12 months:

2 man-years of data-reduction time

In designing the Air Force's giant C-130 "Hercules" Transport, Lockheed Aircraft's Georgia Division tested model after model . . . . measured stresses at up to 500 points per wing as loadings were gradually increased in the test jig. Just a few short years ago, the resulting mountain of raw data would have been a serious stumbling block to the development program. But with the aid of a specially designed Consolidated Automatic Data-Processing System, Lockheed engineers were able to slash data-reduction time to the bone. In just one year's operation, it saved *two man-years of data-reduction time!*

It's a story repeated over and over, wherever data is accumulated in large amounts and processing and reduction time *must* be reduced. Whether the activity is engineering and development testing, as in the Lockheed example, or in process monitoring and control . . . chemical analysis . . . . or general data processing . . . . let CEC's experienced Systems Division look at your problem. The results will pay off for you immediately . . . . and for years to come.

just a few of the system's unusual operating features . . .

. . . balances and reads out up to 200 strain-gage channels at an average rate of 25 channels per minute. Capacity can be increased through additional commutation.

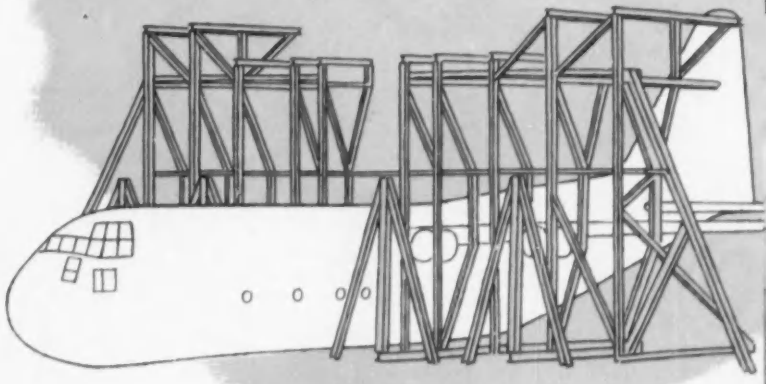
. . . automatically tabulates true, corrected values, in pounds, psi, degrees, etc.

. . . punches a master control tape so that a similar test format can be repeated at any time . . . fully automatically.

. . . provides a punched paper tape for automatic conversion of all bridge outputs to IBM punched cards.

. . . operates with ± 0.1% of full-scale accuracy . . . i.e., resolves d-c inputs greater than ± 1 mv into ± 1000 counts within ± 1 count.

The Data-Processing System designed and built for Lockheed is but one example of the CEC Systems Division's work. For more facts on what CEC Systems Engineering can do for you, write today for Bulletin CEC 1304-X27.





Systems Division

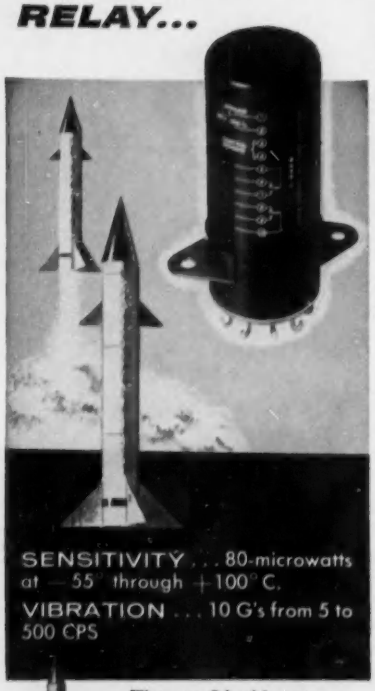
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Electronic Instruments for Measurement and Control

NEW LIQUIDOMETER SENSITIVE RELAY...



The new Liquidometer miniature magnetic amplifier relay, model B250-1, features high sensitivity and vibration resistance.

Designed for use in guided missiles, airborne computers and circuits employing photocells, transistors or thermistors, the new 6 oz. Liquidometer relay has been designed to meet the requirements of MIL-R-5757C and MIL-E-5272A. The B250-1 has virtually no external magnetic fields. It requires no shock mounting.

SPECIFICATIONS

Sensitivity: 80 microwatts from 0-5000 ohm resistive source, decreasing to 100 microwatts for a 15,000 ohm source
Vibration: 10 G's from 5 to 500 CPS
Ambient Temperature: −55° to +100° C.
Contact arrangement: DPDT
Contact life: 100,000 operations at 2 amps resistive
Dimensions: 1¼ in. diameter by 2¾ in. long
Weight: six ounces

For complete details, write Dept. P for Bulletin 562.

THE LIQUIDOMETER CORP

SKILLMAN AVENUE AT 36 ST., LONG ISLAND CITY 1, N.Y.

WHAT'S NEW

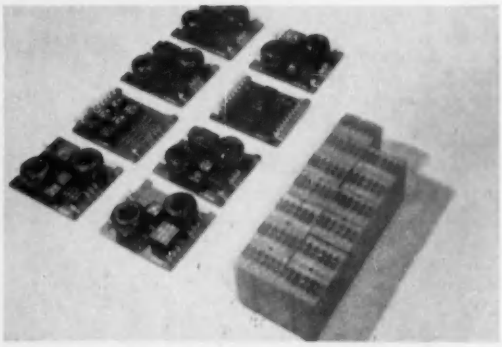
A YEAR FROM MOCK-UP TO MODULE:
Westinghouse Speeds a Product's Evolution

When Westinghouse held its 18th Annual Machine Tool Electrification Forum in Buffalo, April, 1954, an engineers' panel on the stage posed this question to the audience: "What basic change in control apparatus is desired from the electrical industry?" In reply, a member of the audience said, "We really need a control circuit relay with *no moving parts*." The suggestion must have hit home. For just one year later (at the same forum in '55) Westinghouse announced and displayed crude models of a device to do this job. Called "CYPAK", it was reviewed in CtE, June, 1955, page 93. And today, only two years after receiving the challenge, this fast-moving company has completed the evolution of its prototype. The result is a slick, encapsulated, plug-in approach to static element machinery control.

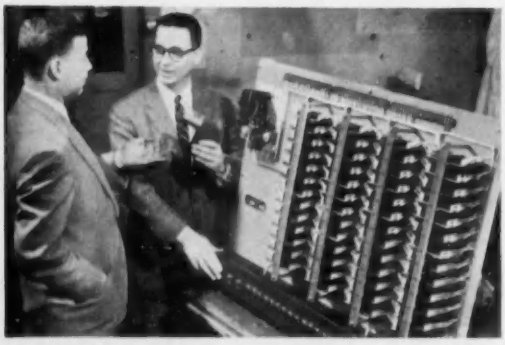
CYPAK's "new look" also reflects practical Westinghouse exchanges with industry. Last year the company conducted eight CYPAK schools for industry in major industrial cities. While teaching the design of logical-type control circuits, company engineers received a hatfull of suggestions on product redesign. The best of these plus several home-grown ideas were used.

Westinghouse has found that a control circuit of "average complexity" can be created by the new CYPAK elements for a cost of about 30 per cent over that for conventional relay control. But while the initial cost is greater, the company insists the reliability, long life, and excellent service features of its new system will make its use pay off in a surprisingly short time.

HOW CYPAK EVOLVED



THE OLD AND THE NEW—13 single-circuit encapsulated elements replace eight double-circuit units of old design. At right is the new plug-in power-channel mounting bar.



VERSATILITY of CYPAK is demonstrated by this billet counter—developed last year for a steel plant.



In color tv, too

CRUCIBLE PERMANENT MAGNETS

for beam correctors, color purifiers and color equalizers give maximum energy . . . minimum size

Designers of electronic and control equipment can count on a *consistently higher* energy product with Crucible alnico magnets. *It means greater power from a minimum size magnet!*

And they're available in practically any size you want—from a fraction of an ounce to several hundred pounds. What's more, Crucible alnico permanent magnets can be sand cast, shell molded, or investment cast to your exact size, shape, or tolerance requirements.

Crucible has been a leading producer of these permanent magnets ever since alnico alloys were developed. And their manufacture is backed by over a half century of fine steelmaking experience. That's why so many magnet applications begin at Crucible.

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WHAT'S NEW

Important Moves by Key People

► The election of **Frank J. Skwarek** to vice-president of Polarad Electronics Corp. parallels the start by Polarad of increased activity in the fields of microwave tubes and medical instrumentation. Emphasis in the latter field will be on low-frequency spectrum analyzers and the application of nuclear resonance phenomena to spectroscopy. Skwarek was with Sperry Gyroscope Co., Doelcam Corp., and Raytheon Mfg. Co. before joining Polarad, where, prior to his election, he had been manager of engineering operations.

► **Bruce Grimm,** who remained with the Precision Potentiometer Div. of Electro Circuits, Inc., when the division was sold to General Controls Co., has been appointed chief engineer of PPD. At about the same time, **Gordon F. Walker** becomes manager of field engineering of General Controls. Grimm will be located at Glendale, Calif., Walker at Skokie, Ill.

► **John A. Doremus,** a pioneer in transistor-circuit applications, has been named vice-president for engineering of Aircraft Radio Corp. He comes to ARC after three years as director of engineering for Allen D. Cardwell Mfg. Co., supervising design of electronic meteorological instrumentation, precision variable capacitors, and communications facsimile equipment.


F. J. Skwarek


Bruce Grimm


J. A. Doremus


E. C. Light


Warren Roberts

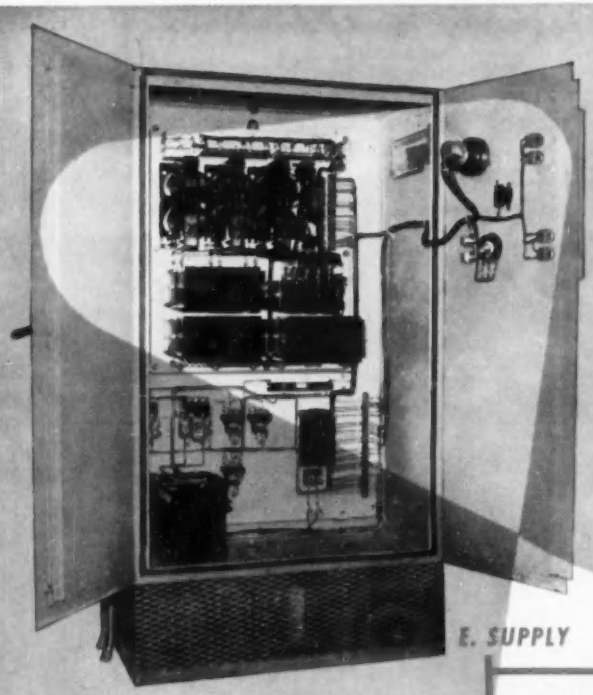

M. V. Hayes


R. O. Fredette


Lee Cahn

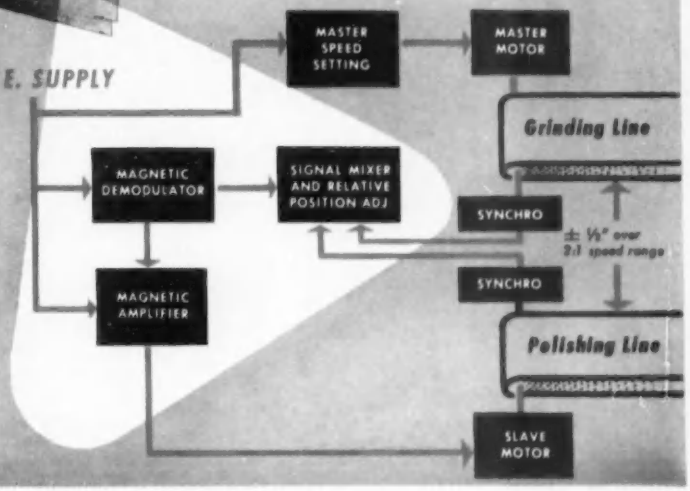

R. H. Williamson

PRECISION SYNCHRONIZATION FOR CONVEYOR



Magnetic amplifier controlled synchronizer unit installed at Mississippi Glass Company, St. Louis, by Hornback and Hardie Electric Company, St. Louis.

with a VICKERS magnetic amplifier control system



IN THE MANUFACTURE of Polished Wired Glass, a series of grinding and polishing operations employing increasingly finer grades of abrasives and a polishing agent is necessary to achieve a smooth, flawless surface. In this particular case, grinding and polishing is accomplished on two separate but parallel conveyor lines.

Since it is necessary that the tables which carry the glass be transferred from one line to the other, and since other machinery must be coordinated with these lines, it is necessary that the relative position of the two lines be synchronized with each other at all times.

A visual method of synchronization which involved a stop-watch and ruler proved unsatisfactory.

The problem is solved by the installation of a Vickers Magnetic Amplifier Controlled Synchronizer. This synchronizer controls the speed of the polishing "slave" line. The speed signal is derived from synchros which detect relative conveyor position. By this technique, the positional accuracy between the two conveyor lines is held to less than $\pm 1/2$ inch throughout a 2:1 speed range for the grinding "master" line.

WRITE TODAY for information on how Vickers Magnetic Amplifiers can help solve your control problems.

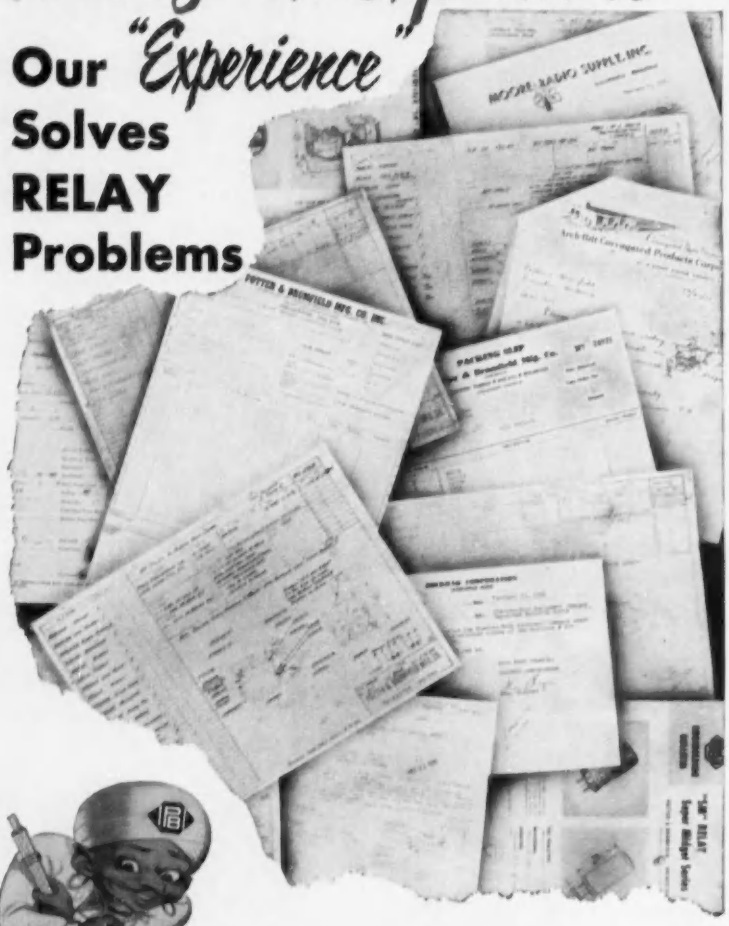
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WHAT'S NEW

As chief engineer of the Carrier & Control Div. of Motorola, Inc., he furthered most of that company's early work in transistor circuitry.

▶ Summes Gyroscope Co. has formed a new division, and has elected a vice-president to supervise it. The new unit: the Research & Quality Div. **Edward C. Light,** the chief officer, has been with Summes since 1946, becoming chief engineer shortly afterward and vice-president for engineering in 1952. Before 1946 he was with Glenn L. Martin Co. and Hughes Aircraft Co.

▶ **Warren Roberts** goes from the potentiometer unit of the Air Force's Cambridge Research Center to Ace Electronics Associates as engineer in charge of its Quality Control Dept. At Cambridge he developed multiple-wiper potentiometers and worked on such projects as the Volscan air traffic control system. During the war he did potentiometer work at the MIT Radiation Laboratory.

▶ A specialist in automatic computing machines has joined the staff of long-range development studies of Jones & Lamson Machine Co. He is **Dr. Miles V. Hayes,** formerly head of the Research Dept. of United Aircraft's Helicopter Section. While with United, Miles supervised machine computations on 'copter design and conducted wind-tunnel experiments on 'copter rotors. He has also been with Hughes Aircraft Co. and Tide Water Associated Oil Co.

▶ Cook Electric Co.'s Cook Research Laboratories Div. has named **Raymond O. Fredette** assistant director of research. Fredette joined Cook Research in 1953 as engineer and chief aerodynamicist. Previous to this, he had been with the Navy Dept., Johns Hopkins University, and Cal Tech.

▶ **Dr. William Shockley,** a pioneer in the development of the junction transistor, has been appointed director of a new Beckman Instruments division bearing his name. The initial staff of the division, known as the Shockley Semiconductor Laboratory, consists of **Dr. G. Smoot Horsley,** formerly with Motorola, Inc., and Bell Telephone Laboratories; **Dr. Leo B. Valdes,** formerly with Pacific Semiconductors, Inc., and BTL; **Dr. William W. Happ,** formerly with Raytheon Mfg. Co. and Sylvania Electric Products, Inc., and **Dr. R. V. James.** The laboratory, now in Mountain View, Calif., will move to permanent quarters in Palo Alto, Calif., next August. New appointments in

NO LEAKAGE
NO CONTAMINATION
NO STUFFING BOX



Lapp PULSAFEEDER CONTROLLED-VOLUME CHEMICAL PUMP

Lapp Pulsafeeder is a combination piston-diaphragm pump for controlled-volume pumping of fluids. Reciprocating piston action provides positive displacement. But the piston pumps only a hydraulic medium, working against a diaphragm. A floating, balanced partition, the diaphragm isolates chemical being pumped from the working pump parts—eliminates need for stuffing box or running seal. Pumping speed is constant; variable flow results from variation in piston-stroke length—controlled manually by hand-wheel, or, in Auto-Pneumatic models, by instrument air pressure responding to any instrument-measurable processing variable.

WRITE FOR BULLETIN 440 *with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Div., 700 Wilson St., Le Roy, N.Y.*

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NEVER BEFORE such a simplified method of telemetering! Over a single pair of wires, multiple control of great numbers of functions is possible. The unit is rugged, compact, economical to run—an ultra reliable machine that affords complete plant control with the push of a button or switch.

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This new telemetering system supervises the control of 10, 16, 20 or 32 plant operations instantaneously!

Combinations of these units can increase control of 100, 250 or even more functions, if needed.

Push button or switch control operates valves, pumps, motors, switches, fans, signals, etc.

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- Wind Tunnel Instrumentation
- Toll Collection Systems
- Digital Computers
- Special Purpose Printers & Instrumentation
- Chemical Analyzers & Control Equipment

WHAT'S NEW

Beckman's Beckman Div.: **Lee Cahn,** formerly chief project engineer, to product line supervisor for infrared spectrophotometers, and **Phil Evans,** formerly with Scientific Supply of Seattle, to spectrophotometer sales engineer. Cahn, who has had previous experience with Askania Regulator Co. and North American Aviation, Inc., is responsible for development of an automatic depth control device for submarines. The Arga Div.'s new sales manager is **Michael S. Dayton,** formerly with Lear, Inc., Sperry Gyroscope Co. (as senior field engineer), and the Armament Laboratory of Wright Air Development Center, Wright AFB.

▶ **R. H. Williamson,** the new manager of Kellogg Switchboard & Supply Co.'s Industrial Sales Dept., was with IBM before joining Kellogg in 1953. His company is a division of International Telephone & Telegraph Corp.

▶ **Elmer P. Wheaton,** chief missiles engineer, heads the contingent of Douglas Aircraft missile specialists now securely ensconced in new quarters in Santa Monica, Calif. On Wheaton's staff are **R. L. Johnson,** assistant chief missile engineer, and **M. H. Hunter,** design engineer. This completes the separation of missile and aircraft engineering functions, a move necessitated by increasing work on guided devices. Douglas is handling eight missile projects at present.

▶ **Frederick M. Rutledge** and **Crayton H. Schwestka,** formerly with Southern Services, power plant designers, and P. R. Mallory & Co., respectively, have been named chief control engineer and chief design engineer, in that order, by The Hayes Corp.

▶ A noted research engineer and consultant to the armed forces has been elected vice-president for research of Norden-Ketay Corp. He is **Dr. Louis Ten Eyck Thompson,** a director of Norden-Ketay and a former director of research. He received the Navy's Distinguished Civilian Service Award in 1952.

▶ Hycor Co., Inc., has appointed **Philip R. Geffe** engineering director at North Hollywood, Calif. He will guide activities in wave filters, magnetic amplifiers, resistors, attenuators, and equalizers. He came to Hycor last November from Triad Transformer Corp., where he had been chief filter engineer.

▶ New manager of the Human Engineering Section of AVCO Mfg. Corp.'s Crosley Government Products Div. is **Dr. Vladimir A. Sklodowski.**

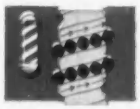
HOW MANY POSITIONING PROBLEMS CAN THESE AMAZING UNITS SOLVE FOR YOU?



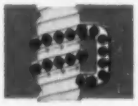
Frankly, we don't know. Almost daily we hear of some new application that never occurred to us. But we do know this: electronics engineers are achieving the "impossible" with Saginaw ball/bearing Screws and Splines, particularly these miniature sizes, from 1½ to 3 inches long.

CHECK THESE UNPRECEDENTED PERFORMANCE ADVANTAGES:

Saginaw ball/bearing SCREWS

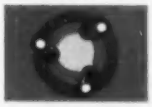


Nut *glides* on steel balls. Like stripes on a barber pole, the balls travel toward end of nut through spiral "tunnel" formed by concave threads in both screw and mating nut.

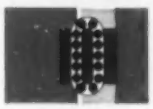


At end of trip, one or more tubular guides lead balls diagonally back across outside of nut to starting point, forming closed circuit through which balls recirculate.

Saginaw ball/bearing SPLINES



The *Saginaw b/b Spline* radically increases the efficiency of transmitting or restraining high torque loads. Instead of *sliding* against each other, the mating surfaces *glide* on rolling balls.



The steel balls recirculate in closed circuits formed by mating longitudinal raceways spaced around the circumference of both inner and outer splines. Guides return balls to starting point.

UP TO 5 TIMES MORE EFFICIENT

Up to 95% efficiency guaranteed in transforming rotary to linear motion; over 80% efficiency, linear to rotary. Require less than 1/5 as much torque as conventional Acme screws for equal output.

SAVE SPACE, WEIGHT, POWER

Permit much smaller, lighter motors and auxiliary equipment. Saginaw b/b Screws have been built from 1½ inches to 39½ feet in length.

PRECISE POSITIONING AND SYNCHRONIZING

Machine-ground types provide precision control within fractional thousandths of an inch, plus perfect synchronization of two or more movements.

OPERATE IN VERY ADVERSE ENVIRONMENTS

Saginaw b/b Screws have been designed and built to operate from −75° to +900° F. Even if lubrication fails or cannot be originally provided, they will still function with remarkable efficiency.

LONG, DEPENDABLE SERVICE LIFE

Accurately predictable life engineered to design requirements. Special Gothic arch groove design and multiple circuits assure dependable performance.

40 TIMES LOWER FRICTION COEFFICIENT THAN ORDINARY SLIDING SPLINES

By applying the same basic gliding ball principle pioneered by Saginaw in the ball/bearing screw, this revolutionary new kind of spline makes practical new engineering designs never before possible.

TRANSMIT OR RESTRAIN HIGH TORQUE LOADS FAR MORE EFFICIENTLY

In any application where column length must change under torque load, the Saginaw b/b Spline offers unprecedented freedom from sliding spline restrictions.

WIDE CHOICE OF ATTACHMENTS

Can be fitted with integral gears, clutch dogs, bearing and sprocket seats or other attachments for use with electric, hydraulic or pneumatic units.

WIDE RANGE OF SIZES AND TYPES

Saginaw b/b Splines have been designed from 3 inches to 9 feet in length, and from 5/8 to 3¾ inches in diameter. To convert push-pull to rotary motion, helical types are available with very high leads, ranging from 20:1 to 100:1.

Saginaw

ball bearing Screws & Splines

MAIL COUPON TODAY FOR NEW ENGINEERING DATA BOOK

Saginaw Steering Gear Division
Ball Bearing Screw & Spline Operation
General Motors Corporation
Dept. 4V, Saginaw, Michigan

Please send your Engineering Data Book to:

Name—Title_____

Firm_____

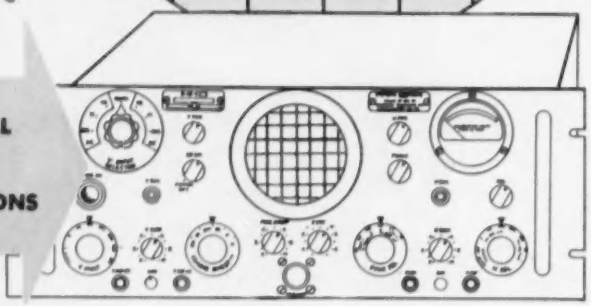
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City_____ Zone____ State_____

SYSTEMS RAKSCOPE

by Waterman

MODEL S-12-C



INDIVIDUAL SYSTEMS ADAPTATIONS

SIZE:
7" x 19" x 10"

ANOTHER EXAMPLE OF Waterman PIONEERING...

The S-12-C series of Systems RAKSCOPES have been developed for the dual purpose of monitoring and troubleshooting of rack-mounted equipment. These oscilloscopes obtain a new degree of flexibility with the multiple input selector making possible selection of different signal sources. This optional vertical input selector, with built-in attenuators, selects either front panel connectors for troubleshooting or rear mounted connectors for systems monitoring. This permits the omission of an entire switching panel from an overall system resulting in circuit and space economies. A ruggedized construction philosophy has been carried throughout. Vertical and horizontal amplifiers are identical, each having a frequency response from dc to 700 kc (—2 db). Their sensitivities are 50 and 72 millivolts rms per inch of deflection. Signal amplitude calibration employs a direct reading meter. The time base is operative in either trigger or repetitive modes with a range from ½-cycle to 50 kc. Synchronization is independent of polarity. Sync. lockout circuits are employed for stable operation over wide range of writing speeds and amplitudes. A unique plug-in elliptical sweep network makes frequency calibrations more simplified. Power requirements: 105-125 volts, 50 to 400 cycles. Accessory probes available; attenuator and amplifier types.

WATERMAN PRODUCTS CO., INC.

PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

MEMO... Write for details today!

WATERMAN PRODUCTS

MANUFACTURERS OF

PANELSCOPE*
S-4-C SAR PULSESCOPE*
S-5-C LAB PULSESCOPE*
S-11-A INDUSTRIAL POCKETSCOPE*
S-12-B JANized RAKSCOPE*
S-12-C SYSTEMS RAKSCOPE*
S-16-A HIGH GAIN POCKETSCOPE*
S-16-B WIDE BAND POCKETSCOPE*
S-16-C COMPUTER POCKETSCOPE*
S-15-A TWIN TUBE POCKETSCOPE*
RAYONIC* Cathode Ray Tubes and Other Associated Equipment

*T. M. REG.

WHAT'S NEW

Others appointed to the section are **Maurice A. Larue, Jr.**, research physicist, and **Frederick W. Trabold, Jr.**, industrial psychologist.

▶ **Melvin Ehrlich** and **Milton Geller** have been appointed senior engineers in U. S. Testing Co.'s Electronics Dept. Ehrlich has been with Signal Corps Engineering Laboratories, the Navy's Electronics Office, and the Physics Dept. of Long Island University, Geller with Magnetic Amplifiers, Inc., and Panoramic Radio Products, Inc.

▶ **Robert R. Mawson** fills Consolidated Electrodynamics Corp.'s new post of project chief for special electronic pressure-sensing equipment. Mawson joined Consolidated in 1951, becoming supervisor of quality control in the test laboratory of the Transducer Div. in 1953 and a specialist in pressure-sensing devices in 1954.

▶ North American Aviation, Inc., continues to build up its Autonetics Div. (CtE, April, p. 42). New assistant to the general manager is **Stanley D. Zemansky**, with the company since 1937 and most recently general supervisor for electromechanical products operations. **Dr. D. B. Duncan**, who becomes assistant chief of the division's Guidance Section, joined Autonetics in 1950 and has been a group leader in analysis and research.

▶ **Allan Beek** takes over the Logistics Contract Computing Center as Logistics Research's new applications manager. He has been a physicist with ElectroData Corp. and has held other positions with Northrop Aircraft, Inc., and Bendix Aviation Corp.'s Computer Div. His center handles contracts for the Alwac computer.

▶ **John L. Dalke**, a member of the National Bureau of Standards since 1947, has been appointed chief of the High Frequency Impedance Standards Section of the bureau's Boulder, Colo., laboratories' Radio Standards Div. **Earle R. Toense**, formerly with ACF Electronics, joins the Digital Circuitry Section of the bureau's Data Processing Systems Div.

▶ **Bruno Chiappinelli** joins Canning, Sisson, & Associates, consultants in automatic data processing and production control systems, to design business systems incorporating electronic equipment. He has had previous experience along these lines: with ElectroData Corp., as digital computer application and sales engineer, and with Hughes Aircraft Co. as business systems analyst and co-director of a group that programmed payroll procedures for a computer.



If fluctuating supply voltage is your problem current Sola literature may aid you

THEORY OF DESIGN AND OPERATION, THE SOLA CV PRINCIPLE NO. CV-210 . . . Technical monograph for electrical engineers and others interested in the underlying electro-magnetic relations of the Sola Constant Voltage Principle. It contains schematic diagrams, vector diagrams, performance curves, and photographs illustrating typical assemblies.

COMPLETE CATALOG BULLETIN (NO. CV-200) . . . Electrical and mechanical specifications for all stock sizes of the five general types of Sola Constant Voltage Transformers and general information on special design service. Also describes typical applications, and gives technical data useful in making a proper selection of size and type. Helpful to design and specification engineers, draftsmen, and electrical technicians.

CONSTANT VOLTAGE DC POWER SUPPLIES (NO. CV-235) . . . Operational data, including charts and diagrams, on new Sola Constant Voltage DC Power Supply assemblies for computing and telemetering equipment, and other applications involving intermittent or pulse loading and/or high amperage requirements. Models available from stock . . . typical assemblies . . . design-and-assembly service.

SPECIAL DESIGN SERVICE FOLDER . . . Outlines the various ways in which the basic CV types and sizes can be modified on order to meet the exact requirements of an application as a component of a manufacturer's product. Special voltages or frequencies . . . special structures . . . multiple outputs. Also lists representative special designs available on "assemble-to-order" basis.

CONDENSED CATALOG CIRCULAR (NO. CV-170D) . . . Complete listing of stock items by volt-ampere rating, input and output voltages, structure type, and catalog number. Handy for purchasing departments, stockmen, and field salesmen.

OPERATING AND SERVICE MANUALS (NOS. CV-171 to 175 incl) . . . Information booklets on installation, service, and repair. In addition, they include valuable operating and engineering data that has proved helpful in getting maximum results under various power system and loading conditions. Manual No. 171 treats Standard Type CV; No. 172, Harmonic-Neutralized Type CVH; No. 173, Adjustable AC Power Supply Type CVL; No. 174, Plate and Filament Power Supply Type CVE; and No. 175, Constant Voltage Transformer for Television Receivers.

SOLA
Constant Voltage
TRANSFORMERS

LITERATURE REQUEST COUPON

Sola Electric Co., 4633 West 16th Street, Chicago 50, Illinois

Gentlemen:
Please send me the literature I have checked below.

- ☐ CV-210
- ☐ CV-200
- ☐ CV-235
- ☐ CV SPECIALS
- ☐ CV-1700
- ☐ CV-171
- ☐ CV-172
- ☐ CV-173
- ☐ CV-174
- ☐ CV-175

Name_____

Title/Dept._____

Company_____

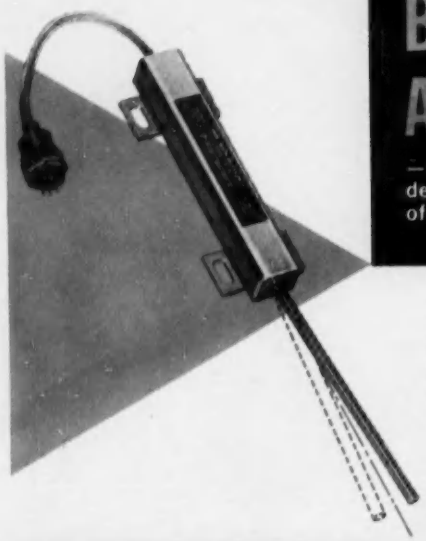
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SELF ALIGNING SHAFT—
linear motion
potentiometers

BOURNS ALIGN-O-POT*

—highly reliable
despite misalignment
of actuating member



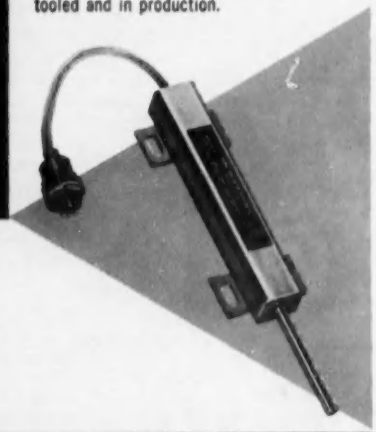
Here is a far-reaching advance in linear motion design. This unit allows for misalignment between the instrument and actuator—eliminating shaft side loads. With no alignment needed, the unit is mounted and installed quickly...is easily designed into a system.

To insure low noise characteristics under extreme vibration, the ALIGN-O-POT wiper assembly is supported throughout its entire travel by parallel guide rods. This provides continuous support directly at the point of contact...multiple contacts are used to further increase the reliability.

The ALIGN-O-POT has a stainless steel case and a flexible cable with plug connector. Standard travels are available from ½" to 6½". Other travels can be provided up to 36". The ALIGN-O-POT is fully tooled and in production.

BOURNS LINIOMETER®

high performance
under environmental
extremes



The LINIOMETER has a bushing-supported shaft and the same highly reliable internal construction as the ALIGN-O-POT—for use where the self-aligning feature is not applicable. Small cross-section and optional mounting configurations are added features of these units. Available in standard travels from ½" to 6½".

the complete line of linear motion potentiometers

Bourns offers a wide selection of standard instruments for any need from ⅛" to 36" travels—all built for maximum reliability and optimum performance. Bourns will work with you on special requirements.
Write for technical literature.

*TRADE MARK

COPR. BL

BOURNS LABORATORIES
General Offices: 6135 Magnolia Avenue
Riverside, California
Plants: Riverside, California—Ames, Iowa

WHAT'S NEW

All Around the Business Loop

► A proposal to trade all of **Electro-Data Corp.'s** 325,000 shares of common stock for half that number of **Burroughs Corp.** stock goes to Electro-Data's stockholders this month. Their approval would combine the two companies and "provide a happy solution to ElectroData's continued growth problems", in the words of Philip S. Fogg, president of ElectroData's parent, **Consolidated Electrodynamics Corp.**

The proposal, made to Consolidated's officers at a special board meeting in March, involves 36 per cent of ElectroData's outstanding portfolio. It followed an announcement by Fogg and John S. Coleman, president of Burroughs, in which Fogg said that the "best interests" of all three companies, Consolidated, ElectroData, and Burroughs, would be served, and that "it is Consolidated's present intention to hold the Burroughs shares for investment purposes."

These shares have a present market value of nearly $6 million, while those to be surrendered by ElectroData have been put at $1 million. Fogg predicted Consolidated's earnings will be increased by as much as 17 cents per share on the basis of current Burroughs dividend payments.

ElectroData, he said, "has experienced tremendous growth in two years of corporate life—in response to growing general management interest in digital computers and particularly in increasing demands for its medium-priced Datatron computer", but "in order to compete successfully with the many strong competitors, now in or about to enter the computer field, it appears necessary to add both high and low-priced systems and additional accessories to the company's line." The proposed combination with Burroughs is epected to accomplish this.

"Capital requirements for research and development, plant expansion, working capital, and particularly for financing leased computer systems," he declared, "will increase greatly in the years immediately ahead. Although ElectroData has arranged for a $4.4 million revolving fund to finance leasing business, which presently accounts for two-thirds of all orders received, 1957 lease-financing requirements alone are estimated at $9 million."

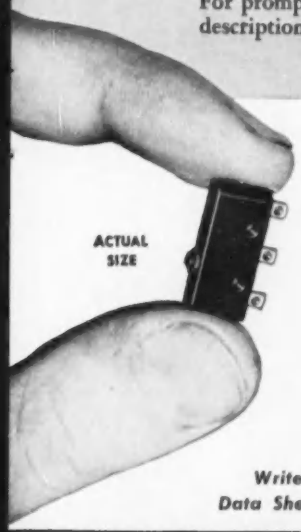
► It's probably news to no one by now, but just for the record, **Westinghouse Electric Corp.'s** 156-day

Electro-Snap Switches Can Be Adapted to Almost Any Job — Quickly, Easily, Economically

Just choose the Electro-Snap Basic Switch that meets your electrical requirements, add the proper actuator — and presto! — you have a tailor-made precision switch that exactly fits your application. Electro-Snap makes a wide variety of stock actuators to fit almost any requirement. And our engineering department is at your service if a standard combination "won't fill the bill."

For prompt action on your switching problems, send us a brief description and rough sketch of the switch you need.

Switching Problem?



SUB-MINIATURE SWITCHES TYPE E-4

S.P.D.T., 1 circuit; 5 amps, 125/250 v. AC Operating force 150 grams max. Exceptionally vibration-resistant. Special model E4-7 is stabilized for — 65° to + 350° F. operation.

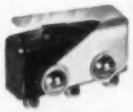
Write for Data Sheet EW-5


Push Button Actuator

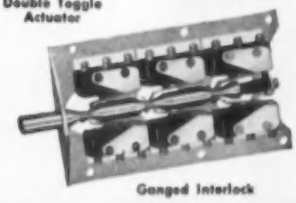

Toggle Actuator (Momentary or Constant Contact)


Double Toggle Actuator


Roller Leaf Actuator


Leaf Actuator


Extension Leaf Actuator

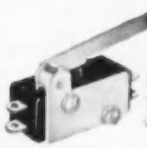

Ganged Interlock

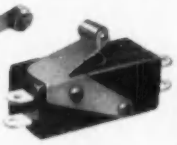
TYPE S SWITCHES Series S1

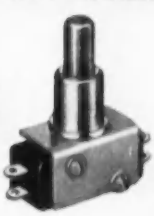


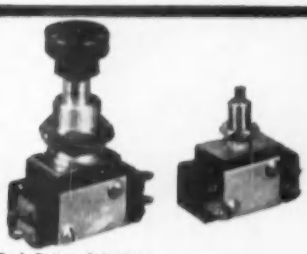
S.P.D.T., 2 circuit; 10 amps, 125/250 v. AC/ 30 v. DC. Ind. Screw or solder terminals on ends or one side of switch. Also available with reset button at bottom of switch or in Type S-100 Make-Before-Break Series where switch completes a new circuit before interrupting old one.

Write for Data Sheet STW-5


Roller Lever Actuator

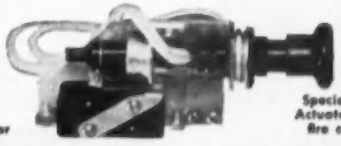

Roller Actuator

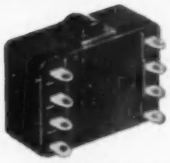



Push Button Actuators (Various button sizes available)


Toggle Actuator (momentary or constant contact)


Extension Leaf Actuator


Special Push Button Actuator designed for fire control system



Write for Data Sheet DW-5

DOUBLE-POLE SIMULTANEOUS ACTION TYPE D-8

D.P.D.T., 4 Circuit
15 amps, 125/250 v. AC.
10 amps, 30 v. DC Ind.
Eight terminals and four separate circuits which operate simultaneously permit switch to reverse 3-phase motors, replace expensive relays, etc.

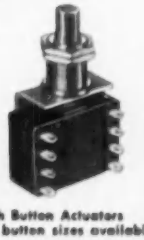

Roller Leaf Actuator


Roller Lever Actuator


Leaf Actuator


Extension Leaf Actuator




Push Button Actuators (Various button sizes available)

HERMETICALLY-SEALED DOUBLE-POLE SWITCH

Write for Data Sheet NJW-5

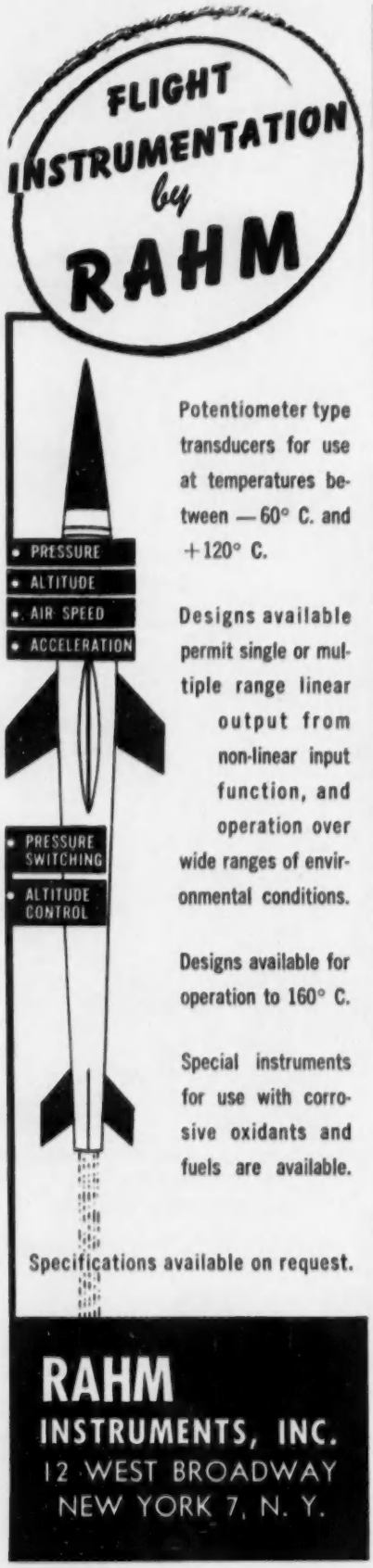

Type J2-4


Toggle Actuator for J2-4

D.P.D.T., 4 circuit 10 amps, 125/250 v. AC/30 v. DC.

ELECTRO-SNAP SWITCH & MFG. CO. 4220 West Lake Street, Chicago 24, Illinois
MANUFACTURERS OF A COMPLETE LINE OF PRECISION SWITCHES FOR INDUSTRY AND AVIATION

ELECTRO SNAP



Potentiometer type transducers for use at temperatures between —60° C. and +120° C.

Designs available permit single or multiple range linear output from non-linear input function, and operation over wide ranges of environmental conditions.

Designs available for operation to 160° C.

Special instruments for use with corrosive oxidants and fuels are available.

Specifications available on request.

RAHM
INSTRUMENTS, INC.
12 WEST BROADWAY
NEW YORK 7, N. Y.

WHAT'S NEW

bloody dispute with the International Union of Electrical Workers (AFL-CIO) is over. The score was: Westinghouse, a five-year contract with the IUE and permission to make time-studies into daywork production jobs involving direct labor; the IUE, arbitration on set production standards, liberalized insurance benefits, and wage increases of 3 per cent in each of the first three years of the contract, and 3½ per cent in the last two.

▶ Promising holders of bachelor's degrees in science and engineering who enter **Raytheon Mfg. Co.**'s new graduate study program will be treated by the colleges they're sent to like any other research assistants. They'll receive a monthly salary of about $240, plus full tuition, campus fees, and book allowances, while working for a master's degree at either Harvard or MIT. Present employees of Raytheon, or undergraduates who contemplate becoming employees, can apply, but all must have been in the

PLANTS A-BUILDING



Ramo-Wooldridge builds in Denver (CtE, April, p. 38): 172,000 sq ft and then some.



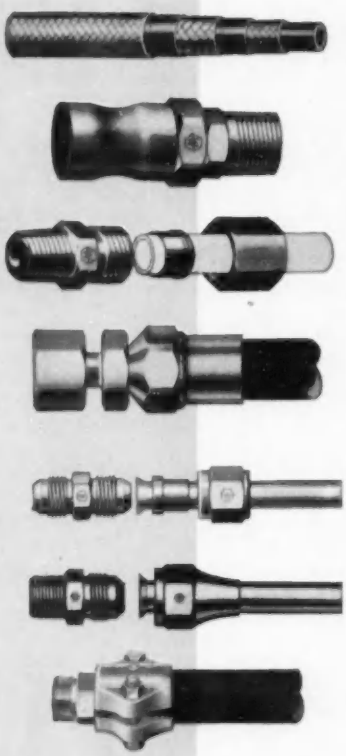
Beckman settlement in Costa Mesa, Calif.: five buildings for its growing Arga Div.



Item in an overhauling: a new headquarters for Richardson Scale in Clifton, N. J.

WEATHERHEAD

...First in Components for Hydraulic Systems



5 TYPES OF INDUSTRIAL HOSE for low, medium, medium-high and high pressure applications; available in complete size ranges; suited for any service condition.

REUSABLE HOSE ENDS for fast assembly and positive, leakproof connections. Rugged construction that cuts costs through repeated use. Designed to insure maximum flow. Only Weatherhead gives you fittings with extra-long gripping area for dependable performance under high pressures.

ERMETO® fittings in steel and stainless steel for leakproof seals without flaring, threading or welding. Withstand shock loads, vibration and impulse at highest pressures. Ermeto connections can be uncoupled and reassembled time after time.

ERMETO REUSABLE HOSE ENDS for connecting hose assemblies directly to block; available from stock in standard sizes. Specified by major diesel manufacturers for high pressure fuel injection lines.

37° FLARED STEEL FITTINGS conform fully to J. I. C. standards. Available in all types and sizes with tube or dry seal pipe thread outlet.

BRASS FITTINGS S.A.E. 45° flare, compression, inverted flare, double compression (threaded sleeve), are machined from extruded stock, giving strength equal to forgings. Large, flat wrench pads provide easy gripping for fast assembly, even in hard-to-reach places.

CLAMP-TYPE REUSABLE HOSE ENDS for all two-wire braid high pressure hydraulic hose applications. No skiving of hose or special tools required. Cadmium-plated, malleable cast iron ends available in sizes ¼", ⅜", ½", ¾", 1", 1¼", 1½" and 2".

WEATHERHEAD FIELD ENGINEERS are readily available to help you gain the advantages of this complete, dependable line..... Weatherhead Catalogs provide complete data on products and applications. Write: The Weatherhead Company, Dept. A-1, 128 West Washington Blvd., Fort Wayne, Indiana.

WEATHERHEAD
THE ONLY SINGLE-SOURCE
HYDRAULIC HOSE AND FITTING LINE.
Available coast-to-coast through
Weatherhead distributors.

WEATHERHEAD
FIRST IN HYDRAULIC CONNECTIONS

THE WEATHERHEAD CO., FORT WAYNE DIVISION
Dept. AC-5, 128 West Washington Blvd., Fort Wayne, Indiana
In Canada: The Weatherhead Co., Ltd., St. Thomas, Ontario

Lepel

HIGH FREQUENCY *Induction* HEATING UNITS

BRAZING
HARDENING
BOMBARDING
SOLDERING
ANNEALING
MELTING

The Lepel line of induction heating units represents the most advanced thought in the field of electronics as well as the most practical and efficient source of heat yet developed for industrial heating. With a background of half a century of electrical and metallurgical experience, the name Lepel has become the symbol for quality in induction heating equipment embodying the highest standards of engineering achievement, dependable low cost operation and safety.

If you are interested in the application of induction heating you are invited to send samples of the work with specifications of the operations to be performed. Our engineers will process these samples and return the completed job with full data and recommendations without any cost or obligation.

TYPICAL INDUCTION HEATING APPLICATIONS



A widely used application in which several assemblies, consisting of a brass body, six radiator fins and a mounting stud, are being soldered simultaneously. The production of similar parts can be further increased by using two work coils and a change-over switch.

The illustration shows a lens grinding block being heated within the dome-shaped work coil. The heat generated in the metal block softens the pitch enabling the operator to remove the ground lenses and insert the next batch. The entire operation is completed in a few seconds.



Electronic Tube Generators—1 KW; 2½KW; 5 KW; 10 KW; 20 KW; 30 KW; 50 KW; 75 KW; 100 KW.
Spark Gap Converters 2 KW; 4 KW; 7½ KW; 15 KW; 30 KW.

WRITE FOR THE NEW LEPEL CATALOG . . . 36 illustrated pages packed with valuable information.



All Lepel equipment is certified to comply with the requirements of the Federal Communications Commission.

LEPEL HIGH FREQUENCY LABORATORIES, INC.
55th STREET and 37th AVENUE, WOODSIDE 77, NEW YORK CITY, N. Y.

WHAT'S NEW

upper portion of their graduating classes, and must be U.S. citizens and under 30 at the time they enter the program. The man to write to for more info is Ratheon's Dr. Ivan A. Getting, vice-president for engineering and research.

▶ The Navy has put in an order for **Servo Corp. of America's** Dead Reckoning Tracer, an air navigation system involving a computer and plotting board. The system, which gives a navigator continuous and instantaneous position readings, is designed to operate over a latitude covering 98 per cent of the earth's surface. Amount of contract: $1,111,925.

▶ Under a $3-million contract with **General Electric, United Shoe Machinery Corp.** will develop, build, and test reactor components for the Knolls Atomic Power Laboratory, which GE operates for the AEC. In charge of the project is the **Atomic Power Dept.** of United Shoe's **Research Div.,** whose testing laboratory in Beverly, Mass., is said to be the first private facility of its kind in the country. United Shoe's announcement, dated March 13, may or may not be a follow-up to one dated Jan. 10, in which it said it had opened a new research unit in Dayton, O., to be coordinated with its principal laboratories in Beverly. The pu pose of the new unit, to be staffed by physicists and electronic and mechanical engineers, was not divulged.

▶ The overseas office of GE's **Research Laboratory** now has a permanent address. It's Pelikanstrasse 37, Zurich 1, Switzerland. In charge is Dr. George J. Szasz, GE's first scientific representative abroad, and assisting him is Victor H. Fraenckel, consultant on scientific relations and director of the company's European-liaison program.

▶ **Battelle Institute,** which has been making studies into the cause and frequency of failure of electronic components and systems, has established an **Electronic Reliability Div.** at Columbus, O., to observe the effect on performance of such factors as high altitude, severe shock, humid or dry atmospheres, extreme temperatures, and acceleration. The components' reactions to sand, dust, and salt-spray will also be studied.

▶ **General Controls Co.'s** new factory branch office in Winnipeg, Can., is the last link in a chain of facilities designed to speed coast-to-coast distribution of the company's products in the U.S. and Canada. There are 42 such offices now in operation, three

REMOTE CONTROLS

RELAYS • SWITCHES • SOLENOIDS • STEPPERS

AIRCRAFT CONTROLS

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THEY SAW
THEY SAID . . .

WHAT! ONLY $7.50 EACH?

1½ AMPERE CONTACTS FOR 115 VOLTS, NON-INDUCTIVE!

YOU SAY THIS STEPPER IS AVAILABLE WITH 4 DISCS?

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Only Guardian Stepping Relays offer so much control at such low cost. Write for special 12-page Stepping Relay Catalog P-84. Compare your most rigid requirements with specifications listed for: ***sequence selecting, counting, programming, pulse multiplying, latching, automatic homing, remote homing, pulse dividing, electrical resetting, slave and master sets, continuous rotation, add and subtract*** and many other types. See how much you can save by specifying GUARDIAN STEPPERS.

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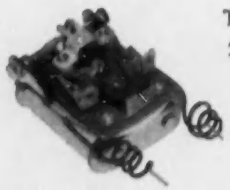
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switching
on
MILLIWATT
signals

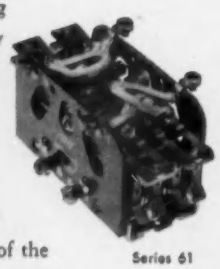
Two Sigma relays, while far from the smallest, lightest or most sensitive, now provide all or nearly all the answers to switching loads in the 1 to 2 KW range on limited amounts of control power. By eliminating the need for a pilot and slave relay combination, either the Sigma 51 or 61, although perhaps more expensive individually, can save in total cost and space.

The first of these, Series 51, was developed for a photoelectric lighting control to switch loads of the order of 10 amperes, with an inrush ratio of 10 to 1. Contact arrangement is SPST, normally closed, sensitivity 100 milliwatts D.C. (3.2 ma, 10,000 ohm coil). Since a coil circuit signal failure will close the circuit, Series 51 also has application in fail-safe alarms.



Series 51

The Series 61 is a polarized latching 20 ampere contactor, requiring only a momentary 1/4 to 1/2 watt signal to latch firmly in either of two positions. Permanent magnetic instead of mechanical latching forestalls the life-shortening wear of triggers and catches. Each "throw" of the 61 opens two circuits and closes two others. It may be wired DPDT. When operated not more than once per second, Series 61 has a minimum rated life of 100,000 cycles on 20 ampere resistive loads at 28 VDC or 115 VAC. The advantages of such a pulse-operated sensitive contactor are apparent in battery-energized supervisory control systems, as well as in controls for production machinery where contactors must be immune to vibration and the effects of wear.



Series 61

Further information available on request.

SIGMA

SIGMA INSTRUMENTS, INC.,
69 Pearl Street, So. Braintree, Boston 85, Massachusetts

WHAT'S NEW

of which are in Canada and two in British Columbia.

▶ The **Research & Control Instruments Div.** of **North American Philips Co.** has revised financing and rental terms on purchases worth $2,500 to $50,000. The finance charge for outright purchases is 6 per cent simple interest a year, while the rental charge, based on cost of equipment plus installation, is 3¼ per cent the first year, 3 per cent the second, 2¾ the third, 2½ the fourth, and 2¼ the fifth and succeeding years. All leases run a minimum of 30 years.

▶ **Beckman Instruments, Inc.,** is sponsoring a three-times-a-week radio program for engineers in Southern California. The 5-min "News for Engineers" is prepared by A. X. Schilling, editor-publisher of "Engineer of Southern California" and is broadcast at 10:15 p.m. over Los Angeles station KFI. Beckman's **Arga Div.** has purchased the entire mechanical and electro-mechanical line of **Belock Instrument Corp.** The line includes high-speed magnetic clutches, servo motor gear heads, limit stops, dial assemblies, and remote control positioners.

▶ Users of **Benson-Lehner's** data reduction machines can choose one of two world-wide servicing programs recently inaugurated by the Los Angeles company. One, purchased at a fixed annual rate, pays for all expenses exceeding 7 per cent of an installation, and covers maintenance visits, emergency calls, and parts and materials. The other, a time and material contract, provides regular service plus any additional calls. A service-control plotting board puts B-L in touch with every one of its installations.

▶ The **Missile Engineering Dept.** of **Allen B. Du Mont Laboratories, Inc.,** is being transferred from Clifton, N. J. (CtE, March, p. 32) to new headquarters in Los Angeles. Melvin B. Kline, formerly manager of government and special project engineering for the **Technical Products Div.,** has been promoted to manager of the missile department.

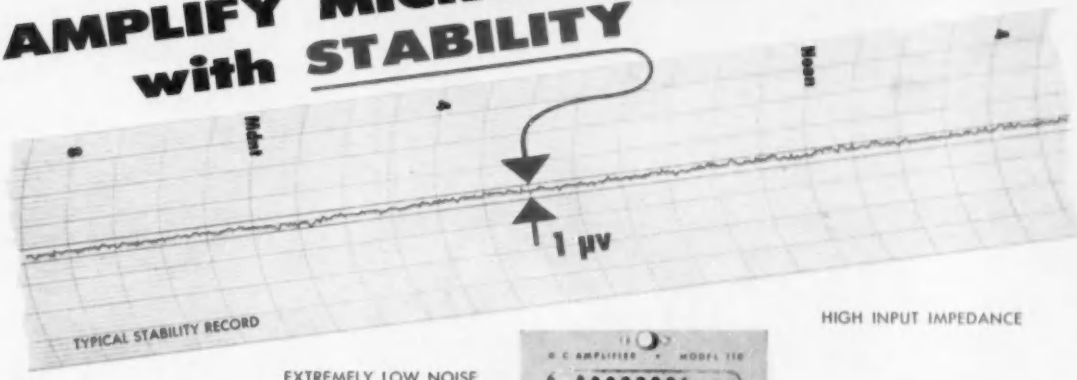
▶ **The Gamewell Co.** has expanded its **Engineering & Development Dept.** under Fred Vacha, potentiometer engineering manager; organized a new **Prototype Dept.** in its **Precision Potentiometer Div.** under Allen Graybeal; appointed Charles J. Manning, formerly special products manager, manager of potentiometer field engineering, and named John T. Bales, former sales engineer, sales manager for PPD.

▶ Under a new corporate setup, opera-

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CALIFORNIA

DC DECADE AMPLIFIER

AMPLIFY MICROVOLTS with STABILITY



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10 ACCURATE GAIN RANGES

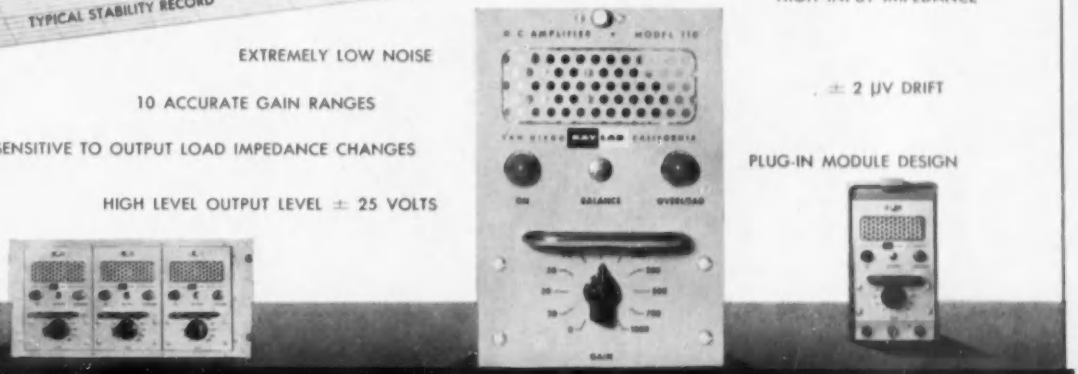
INSENSITIVE TO OUTPUT LOAD IMPEDANCE CHANGES

HIGH LEVEL OUTPUT LEVEL ± 25 VOLTS

HIGH INPUT IMPEDANCE

± 2 μV DRIFT

PLUG-IN MODULE DESIGN



The new KAY LAB Model 110 Amplifier is a low drift, high gain, chopper stabilized, broad band DC amplifier incorporating proven KAY LAB chopper amplifier circuitry. Small modular plug-in construction makes it ideally suited for group rack mounting as a part of permanent instrumentation facilities or as a general laboratory instrument in a portable cabinet. Ten precise feedback controlled gain ranges are provided. Low noise allows accurate amplification of microvolt signals. A completely new and unique output circuit provides unsurpassed linearity and dynamic performance — unaffected by output load impedance variations over a wide frequency range.

APPLICATIONS: Ideal strain-gage amplifier . . . vibration studies . . . transducer amplifier . . . scope preamplifier . . . single or multiple channel recorder driver . . . impedance matching "DC transformer" . . . general laboratory instrument wherever precise gain is required for amplification of microvolt signals.

SPECIFICATIONS

Gain	0, 20, 30, 50, 70, 100, 200, 300, 500, 700, 1000 ± 1% DC
Input Impedance	100,000 Ω
Frequency Response	± 3% DC to 10 kc, less than 3 db down at 30 kc
Phase Shift	Less than 5° to 2 kc
Equivalent Input Drift	± 2 μv when used with regulated line voltage
(over 40 hour period)	± 10% change in AC input causes less than ± 5 μv change after 10-minute warm-up
Equivalent Input Noise	0 to 3 cps, less than 5 μv peak to peak 0 to 750 cps, less than 5 μv RMS 0 to 50 kc, less than 12 μv RMS
Chopper Intermodulation	Less than 0.1%
Linearity	Better than 0.1% to 2 kc
Output Impedance	Less than 1 Ω in series with 25 μh
Output Capability DC	0 to ± 25 volts with load impedance greater than 1000 Ω 0 to ± 25 ma with load impedance from 10 to 1000 Ω

POWER REQUIRED	0.9 watt each unit plus 0.6 watt each adaptor
Dimensions: Amplifier unit	5" wide, 7¼" high, 14¼" deep
Unit in cabinet	6" wide, 9⅛" high, 18⅜" deep
Rack adaptor for 3 units	19" wide, 8¾" high, 18⅛" deep
Net Weight	15 lbs.
Shipping Weight	30 lbs.

PRICE: Amplifier Unit	$590.00
Cabinet (with fan and connector)	50.00
Rack Adaptor (with fans & connectors)	150.00

Kay Lab reserves the right to change specifications and prices without notice.

...the Standard in chopper-stabilized instruments

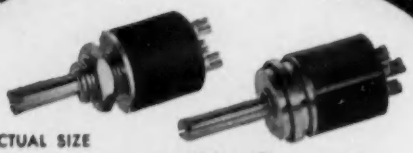
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UP TO 100 K

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NOW YOU CAN specify a Waters pot for your miniaturized designs that require 50K and 100K potentiometers. In the reliability-proved construction of the AP-½, these new, higher values give you:

- ***Resistances — 10 ohms to 100 kilohms***
- ***Ganging — up to four units***
- ***Three mounting styles — plain-bushing, split-bushing, or servo***
- ***Three terminal styles — radial, axial, or wire-lead***
- ***Automation models — for printed circuits***
- ***Encapsulated designs available***

General specifications: Centerless-ground, stainless-steel shaft can be sealed with O-ring; gold-plated, fork-type terminals; 2% standard linearity for 50K and 100K — 5% for lower values; temperature range —55 to +105C, to 125C on order; 2 watts at 80C; anodized aluminum body ½" diameter × ½" long — ⅝" long for 100K; corrosion-resistant-alloy bushing; all electrical connections spot-welded or soldered; furnished with stops or for continuous rotation. *Write for data sheet on these dependable ½" potentiometers.*

Do you ever need pots that are "just a bit different"? Maybe we can help you — by modifying a standard Waters design or by taking a bold, new approach. Tell us your need and we'll tell you what we can do.

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MFG. INC.

WHAT'S NEW

tions of **Electro Tec Corp.** and its two divisions, **Electro Tec of Florida, Inc.,** a subsidiary, and **Instrument Corp. of America,** have been consolidated. At the same time, facilities in Florida, Virginia, and New Jersey have undergone expansion. Electro Tec credits "an unprecedented demand" for its precision slip ring and commutator assemblies with the move.

► **Farrand Optical Co., Inc.** has formed **Farrand Controls, Inc.,** to take over manufacture and distribution of the former's Inductosyn automatic control equipment.

Around the construction circuit:

► A $2-million plant for **Beckman Instrument's Helipot Div.** in Newport Beach, Calif., to consolidate all of Helipot's widespread Southern California facilities. Completion is set for late next fall. Expected personnel: 2,000. Initial buildings will contain more than 15,000 sq ft of floor space. Some functions will continue in Mountainside, N. J., and Toronto, Can.

► Five buildings (45,800 sq ft) in Costa Mesa, Calif., to accommodate Beckman's **Arga Div.,** whose employees have increased in eight months from 68 to about 200. The first Arga contingent goes to Costa Mesa in July.

► Another for **IBM** (CtE, April, p. 35), this one for its **World Trade Corp.,** which handles all IBM business outside the U. S. The eleven-story building, to rise up on United Nations Plaza in New York City, will be completed at year's end.

► A 22,000-sq-ft, multiple-building development in Concord, Calif., to house **Donner Scientific Co.'s** engineering laboratories, manufacturing facilities, and administrative offices, all now in Berkeley, Calif. Initial cost: $250,000. Completion is scheduled for June.

► Surface-barrier transistor facilities in Concord, N. H., for **Sprague Electric Co.** (CtE, March, p. 32). The 20,000-sq-ft plant, Sprague's twelfth for the manufacture of electronic components, will open next fall with about 200 employees. General manager will be Jesse Ault, formerly with **General Electric Co.**

► A guided-missile development center in Denver for **Glenn L. Martin Co.** (CtE, April, p. 38). About $10 million is going into the first phase of the project, which will employ 5,000 at peak production, expected in four years. About 1,000 of them will be scientists. General manager is Albert L. Varrieur.

ASCO

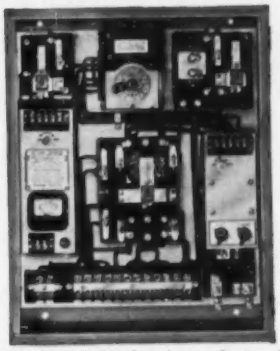
the one source for
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that offers engineers complete design flexibility

When designing equipment requiring electromagnetic controls, many engineers have found it saves them money if they first talk with an ASCO engineer before specifying solenoids, contactors or relays. His advice will help you cut initial cost, improve your final product and simplify automatic control.

Most important, the ASCO representative can recommend not only standard and special purpose controls, but can also offer the development services of ASCO, the one source that offers engineers complete design flexibility. His knowledge will allow your imagination free rein—unshackle you from the limits of designing with only conventional controls in mind.

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ASCO engineered and manufactured panels are provided by combining ASCO controls with purchased equipment as needed.

AC SOLENOIDS



104S1
Stroke up to ¾"



104S4
Stroke up to 1⅛"

DC SOLENOIDS



106S4
Stroke up to 1"



106S14
High Pull
Stroke up to 1"



106S76
Fuel throttle control.
Stroke up to 1¾"

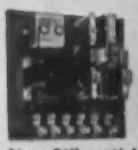
SPECIAL PURPOSE RELAYS



Reverse Current



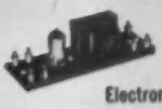
Brake Motor Time Delay



Close Differential

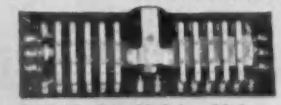


Coil-less

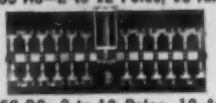


Electronic

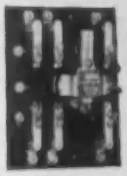
MAGNETICALLY HELD RELAYS



1055 AC—2 to 12 Poles, 10 Amp.

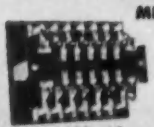


1058 DC—2 to 12 Poles, 10 Amp.



1054 AC—
1 to 3 Poles,
25 Amp.

MECHANICALLY HELD RELAYS



1256-168S—AC
2 to 12 Poles, 10 Amp.



1255—AC-DC
1 to 5 Poles, 25 Amp.

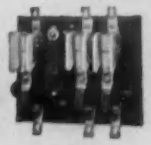


1255-166S—AC
1 to 6 Poles, 25 Amp.

CONTACTORS



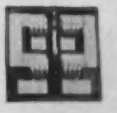
Contactors for computers



1035 AC, Normally Open



1045 AC-DC, Double Throw



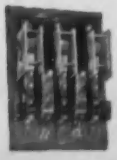
1025-111S DC, Low Voltage, High Amperage



1044 AC-DC, Normally Closed



1025-131S DC, Field Discharge



911-187S, AC-DC, Feeder Switches



AC-DC, Marine Duty

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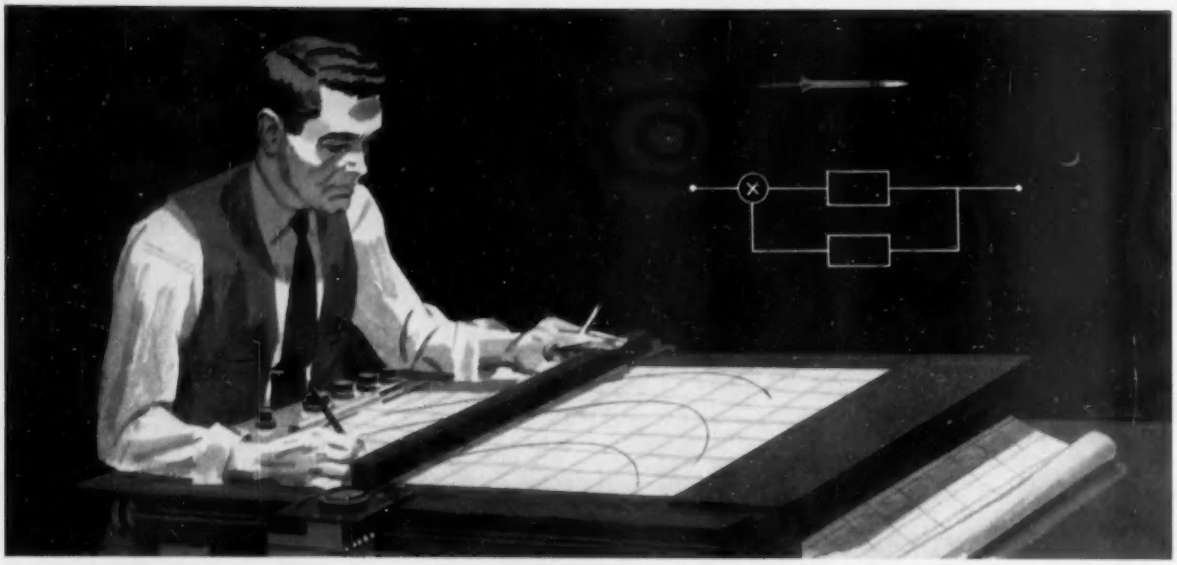
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MISSILE GUIDANCE AND CONTROL... In applying advanced servo and noise-theory techniques to missile control systems, JPL has led and advanced the field of missile guidance.

Among specific achievements are the application of Wiener RMS methods to multiple-input, multiple-loop servos, and matching missile trajectory to missile control transfer function for optimum accuracy.



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The Jet Propulsion Laboratory is an organization devoted entirely to scientific research and development. Covering an 80 acre area in the rising foothills of the San Gabriel mountains, north of Pasadena, it occupies an ideal location close to residential districts.

The working staff of the Laboratory consists of about 1250 people, all employed by the California Institute of Technology. The various projects are conducted under continuing contracts with the U. S. Government.

The prime objective of JPL is obtaining basic information in the various sciences related to missile systems development and in all phases of jet propulsion. Underlying the entire Laboratory activity, a major continuous program of fundamental research in the physical sciences is constantly in progress.

In its missile system and jet propulsion undertakings, the Laboratory maintains a broad technical responsibility, from basic research to prototype engineering. By virtue of this and the integrated nature of the JPL technical staff, each individual is drawn into close contact with the general field to which his specialized technical abilities contribute the most.

If you are interested in knowing more about our work and the specific employment opportunities now open, please send us an outline of your technical background and experience.

CALTECH jpl **JET PROPULSION LABORATORY**

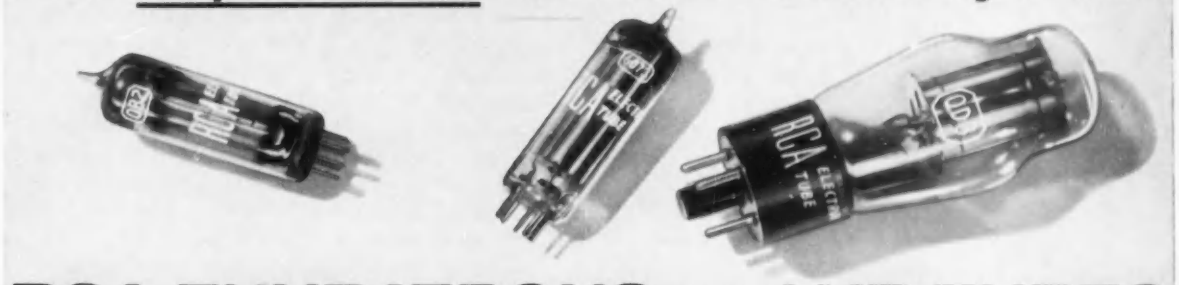
A DIVISION OF CALIFORNIA INSTITUTE OF TECHNOLOGY

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For dependable control . . . always use



RCA THYRATRONS and VR TUBES



At the heart of industrial-electronics equipment are electron tubes. The continuous operation of many industrial production lines *depends* on the performance of these tubes—thyratrons for "on-off" operations, voltage-regulator tubes for dc voltage stability.

RCA . . . world renowned for advanced-design superior-quality electron tubes . . . offers a group of Thyratron and Voltage-Regulator tube types specifically designed for *dependable* control of industrial-electronic apparatus. Shown here are 10 of the RCA types most frequently specified.

RCA TYPE	DESCRIPTION
	Voltage-Regulator Types
0A2—miniature 7-pin base 0A3—octal 6-pin base 0B2—miniature 7-pin base 0C3—octal 6-pin base 0D3—octal 6-pin base	For regulation of dc voltage supplies for amplifiers, oscillators, etc. Also can be used as relaxation oscillators.
6073—miniature 7-pin base 6074—miniature 7-pin base	Like 0A2 and 0B2 but having very stable characteristics and intended for applications critical as to shock and vibration.
	Relay Type
5823—miniature 7-pin base	For use where "on-off" control of low-current electrical circuits is required.
	Thyratron Types
2D21—miniature 7-pin base 2050—octal 8-pin base	Primarily intended for high-sensitivity relay control circuits.

Send for these booklets today!

#RIT-104—Receiving-Type Tubes for Industry and Communications . . . contains up-to-date data on 130 RCA receiving-type tubes especially suited to industrial electronics.

#ID-1020-A—RCA Interchangeability Directory of Industrial-Type Electron Tubes . . . time saving information. Lists industrial tubes of 26 manufacturers and gives RCA direct replacement types or RCA similar types, whichever is available.

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A MESSAGE TO AMERICAN INDUSTRY • FIRST OF A SPECIAL SERIES

THE SHORTAGE OF SCIENTISTS AND ENGINEERS: *How Critical Is It?*

The United States is running into a serious shortage of scientists and engineers. There is no novelty in this observation. It has often been made in the last few years. And there has been mounting alarm about what this shortage may mean for both our national security and our prosperity.

There would be great novelty, however, if general agreement were attained on such important matters as the size of the shortage, the extent of the damage it threatens to inflict, and the best ways to eliminate it. The purpose of these editorials is not to provide this novelty, but to ventilate some of the key aspects of the shortage of scientists and engineers.

This first editorial in the series is designed to throw light on the over-all dimensions of the shortage. Others will be addressed to such questions as:

- How serious is the threat to our economic well-being and to our national security?
- What needs to be done to prevent the shortage from becoming critical?

Rise in Technical Manpower Has Been Rapid

The problem is *not* that we have been producing a small number of engineers and scientists. Indeed, the number has risen sharply. We now have a working force of more than 600,000 engineers, over twice as many as the 286,000 there were in 1940. And we have about 250,000 scientists (chemists, physicists, biologists, geologists, mathematicians, etc.), compared to only 92,000 in 1940. About one in 148 persons in the labor force of 1940 was a scientist or engineer; today the ratio is about one in every 80.

In research and development work, where highly creative scientific minds are required, there has been fully as rapid a rise in employment of scientists and engineers. Fewer than 90,000 were employed in research and development fifteen years ago; the total now exceeds 200,000.

. . . But Not Rapid Enough

Despite this rapid increase in the number of scientists and engineers—at a rate much faster than the increase in the labor force as a whole—the needs of industry, government and education for technically trained people have risen even more sharply.

The principal reason for this mounting demand is the prodigious growth of research in the last 15 years. From a total of only about $900 million spent on all types of research in 1941, the annual expenditure rose to over $5 billion by 1953 (the latest estimate available). Over two-thirds of the research is done by private industry, mostly to develop new and better products and to find new and better methods of production. Most of the rest is performed by the government, largely to develop improved and inevitably more complex scientific weapons.

One aircraft company has found from its own experience that it required 17,000 engineering manhours to develop a typical fighter plane in 1940. The requirement is now about 1.4 million engineering manhours. Development of the typical fighter plane of 1960 will require well over 2 million engineering manhours.

In this dramatic example, the need for engineering services for a basic piece of military equipment soared 80 times in 15 years. It is an indication

of why the demand for more and more technically trained men and women has outstripped even the imposing increase in scientific and engineering manpower of the last decade and a half.

Size of the Shortage

Exactly how great the gap is between the available supply of scientists and engineers and the number required, it is impossible to say. In some instances technical talent undoubtedly could be better used than it is now. And part of the shortage might "disappear" if higher salaries had to be paid. (These questions will be discussed in later editorials.) But informed estimates of the approximate size of the gap can be given.

● According to the best available information, from estimates by the Engineers' Joint Council and the U. S. Bureau of Labor Statistics, **the minimum need for engineers from graduating classes is 40,000 each year for the next ten years.** Last year we graduated only 23,000 engineers, just about enough to cover replacement needs without allowing for any expansion of the number of active engineers. Projections made by the U. S. Office of Education indicate that we shall probably not have a class of 40,000 – the *current* annual requirement – until 1963.

● According to Dr. Howard Meyerhoff, executive director of the Scientific Manpower Commission, **there is now a shortage of about 20,000 scientists.** Last year the number of doctoral degrees in the natural sciences, almost a prerequisite for research work, was only 5,000. Dr. Meyerhoff estimates that the shortage of scientists will rise another 30,000 by 1960.

More Needed as Teachers

Not all of the graduates with scientific and engineering training, furthermore, will work as scientists and engineers – that is, by performing research and giving it practical application. Such training is now necessary in many sales and management positions. And more of our technically trained men and women must remain in educational institutions as teachers if the quality of engineering and scientific education is to be maintained. A survey in 1954-55 by the National Education Association showed that, out of 277 universities, state colleges and large private colleges, nearly one-third *already* had unfilled vacancies in engineering and three-fourths had vacancies in physical sciences.

The dimensions of the shortage of scientists and engineers can be summarized as follows: **Despite a substantial rise in the trained manpower available, the needs of industry, the government and education have risen still faster. The best information indicates that, on the basis of current and anticipated needs, our recent yearly rates of production of slightly over 20,000 engineers and about 5,000 PhD's in natural sciences could be doubled without closing the gap entirely.**

The disturbing implications of this shortage for our national security and our prosperity and some practical suggestions for eliminating it will be the subjects of subsequent editorials in this series.

This is one of a series of editorials prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments of particular concern to the business and professional community served by our industrial and technical publications.

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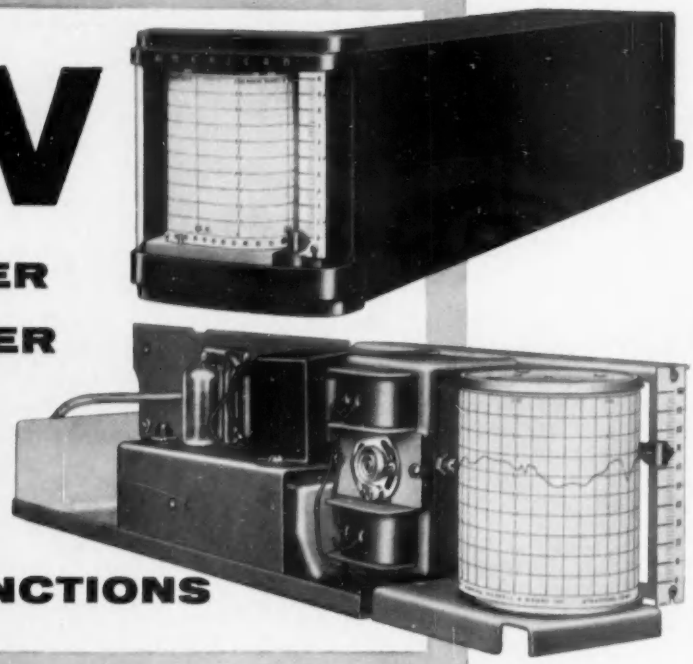
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ACCURACY: ± 0.5% of span. **SENSITIVITY:** ± 0.2% of span. **REPEATABILITY:** ± 0.25% of span.

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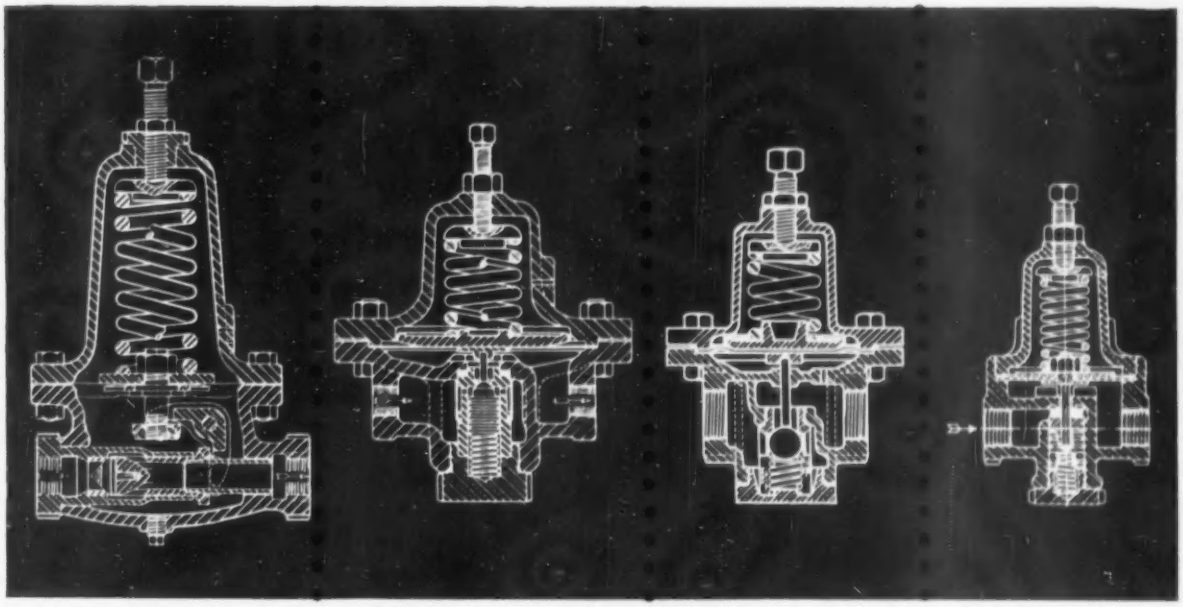
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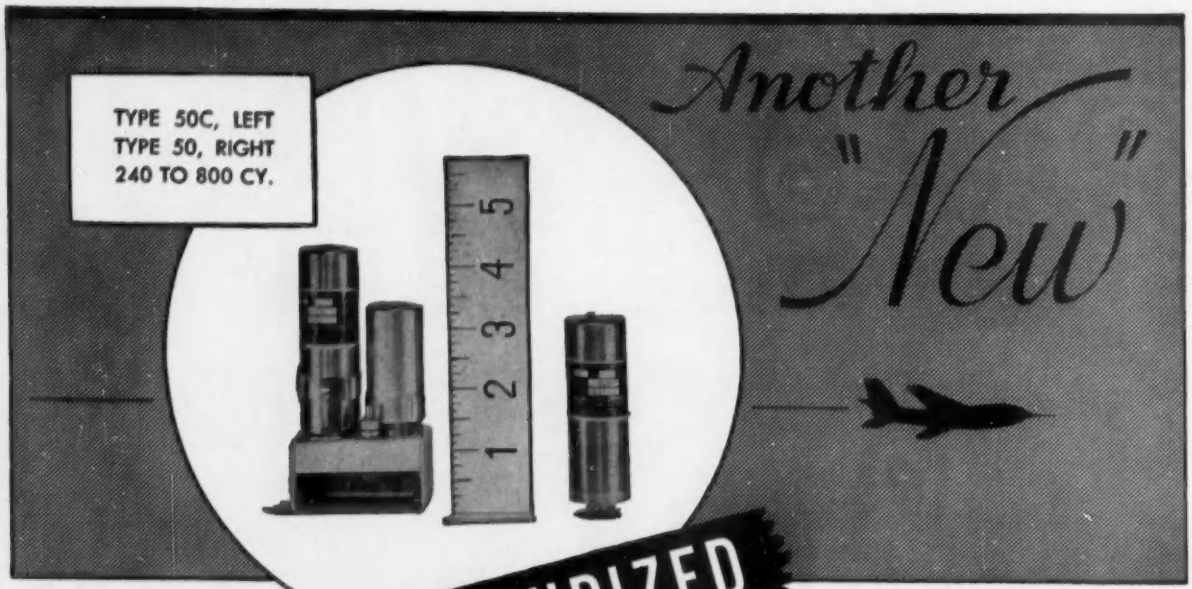
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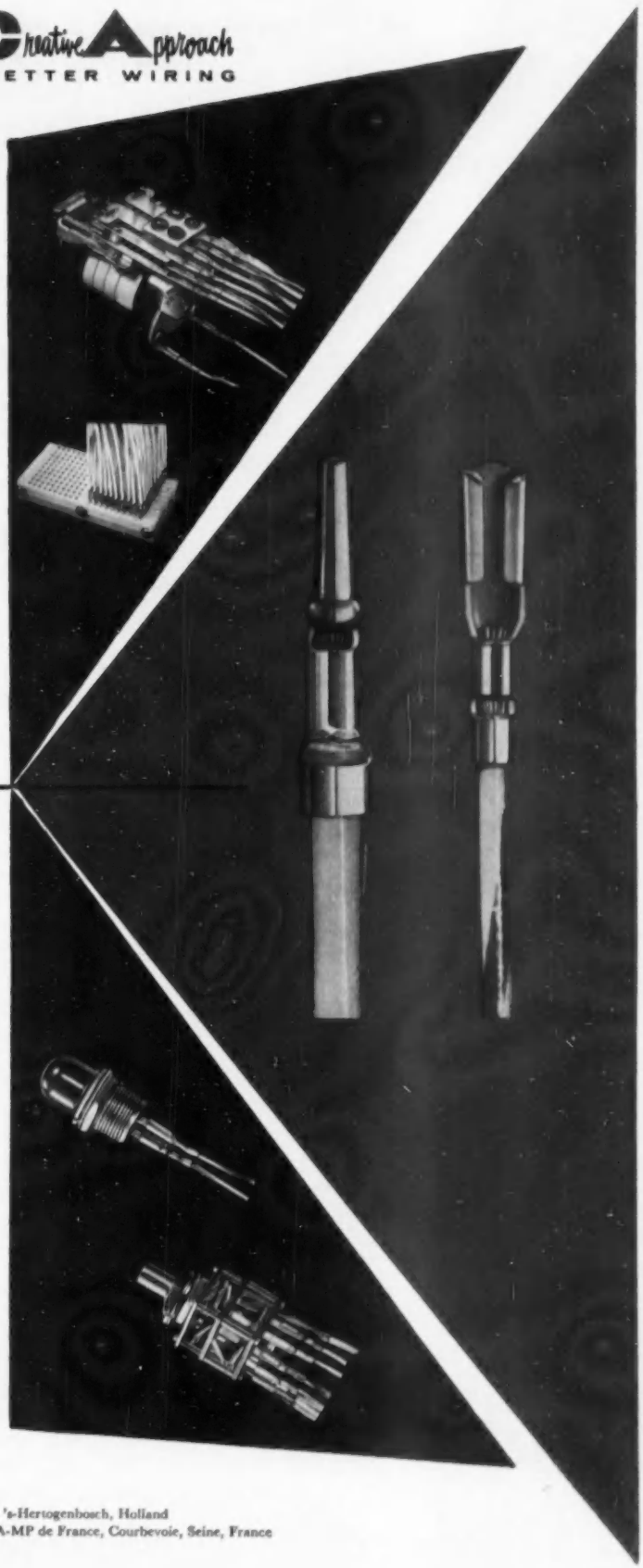
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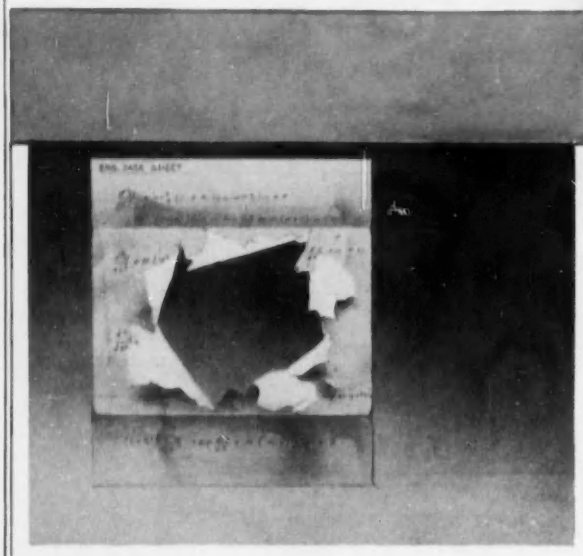
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Control Glimmers Inside Latin America

Were Horace Greeley editing a technical journal today, he'd surely advise, "Go south, young man." For the 20 republics of Latin America are bounding into an era of economic growth fraught with opportunities as golden as the West's of the 1860's, and they're waiting for the adventurous engineer.

Up to $2 billion yearly for new industries

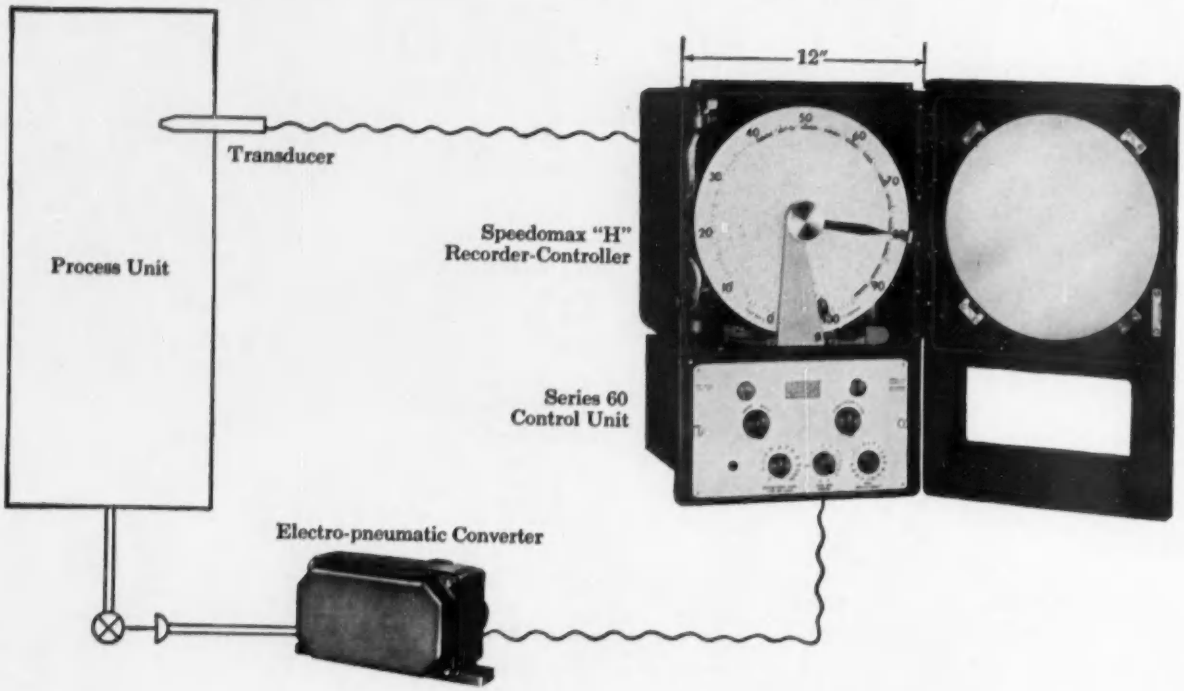
The potential really shaped up in the past 20 years. Average yearly increase in gross national product climbed to a remarkable 4.7%, with production passing the $40-billion mark in '51. And economists reckon that rising personal income (with 7% of the world's population and 19% of its usable land) will spur capital investments in new industries to an unprecedented 18% of the yearly product net.

Control technology and its hardware will obviously bounce strongly along with Latin America's modern industry. How much of this technology already exists? How much is domestic and how much comes from the U. S. and other countries? During the past year foreign offices of the U. S. Department of Commerce surveyed local use of control equipment. Reports now in, from Bolivia, Venezuela, and Peru, suggest that some important control trends already exist inside Latin America.



Germany and the United States split a market

In this mountain-bound land, industrial development is still in "low gear". But contracts have been placed with foreign promoters for sugar mills, chemical plants, and match factories. Right now, mining is still the big industry, followed by oil, power, and textiles. All instrument and control needs are met by imports, with the U. S. and Germany in ardent competition for the $424,000 industrial-control market that materialized in '52-'53. Germany was 'way ahead in measuring and test equipment: most of its $224,000 export was in electrical quantity, gas, water, and size meters. The U. S. excelled in automatic control devices and process instrumentation—these accounted for 90% of its $200,000 export. Major U. S. items: primary switchboards and panels, motor controls. The



L&N'S NEW C.A.T. ELECTRO-PNEUMATIC CONTROL

gives you these advantages:

- **FAST ELECTRICAL RESPONSE** in measurement, control, transmission.
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- **EASY INSTALLATION** with only 1 pair of leadwires from the control unit to the converter mounted near the process; then short air lines from converter to valve.

L&N's C. A. T. (Current-adjusting type) Control combines the advantages of pneumatic valve operation with the flexibility and fast response of an electrical control system. The electrical signal produced by a change in the process variable passes from transducer, to Speedomax recorder, to L&N Control Unit. Here, the properly tuned combination of proportional, rate, and reset actions produces a control current which is fed to the Electro-pneumatic Converter. The Converter matches the control characteristics of the current output with an air pressure which operates the pneumatic valve.

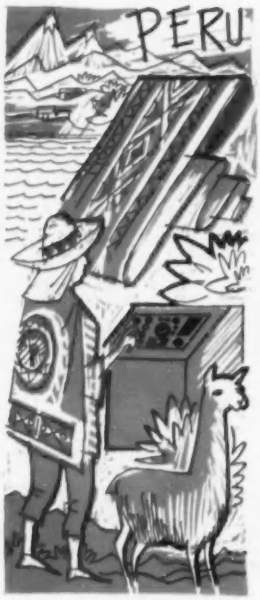
The L&N Control Unit and all of its replacement parts are "plug-in" type for fast, easy servicing. The Unit's proportional band is adjustable from 0 to 500% of recorder range, rate time is continuously adjustable from 0 to 8 minutes, and reset action runs from 0 to 100 repeats per minute.

The force-balance type Electro-pneumatic Converter is ideal for installation directly on the process unit. It can be mounted anywhere, in any position; is vibration-resistant and weather-proof. Its minute (5 milliamp) current and continuous air purge provide a wide safety margin for operation in hazardous areas. If power fails or the control unit is removed, the control valve is sealed in its last position. And the Converter is so sensitive that its dead band is less than 0.1%.

C. A. T. Electro-pneumatic Control may well be the answer to your control needs. For details, write for Folder ND4(8). The address—Leeds & Northrup Co., 4918 Stenton Ave., Phila. 44, Pa.

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only automatic control devices from Germany were highly specialized and custom-built. Note to manufacturers: import permits lenient; controls are "essential to the economy".



Swiss are a prime contender

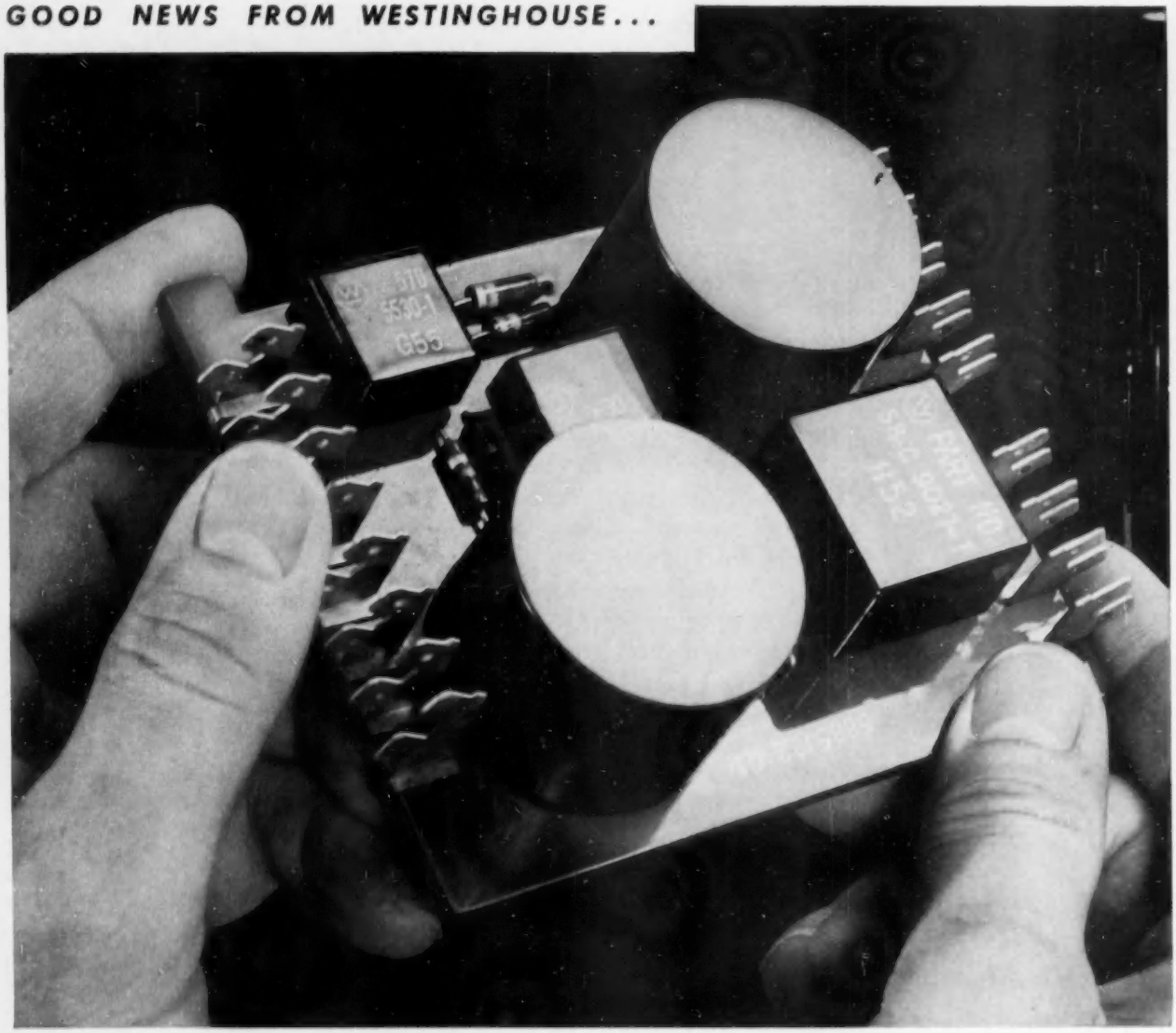
Industrial progress has already hit "second gear" in this rugged, narrow nation along the Pacific. Mining, chemical, and drug plants are starting to vie with textiles, now chief export industry. Just north of Lima a huge industrial area—featuring hydroelectric and steel plants—is now a-building. In '52 Peru brought in over $3 million in control equipment. About 60% of this came from the U. S., with Switzerland the other major supplier. The Swiss specialized: they furnished, aided by Britain and Canada, over 80% of the electrical quantity-measuring items and 27% of all automatic control devices. The U. S. dominated process instruments (near $200,000); also did well in motor controls, primary switchboards, and control valves. German inroads were evident—gains of from 1% in '50 to 28% in '53 in meeting Peruvian needs for mechanical gaging and test instruments, and invasion of the control device market (35%). Note to manufacturers: much control equipment gets into Peru duty-free, while the rest suffers a very modest per-weight stipend.



Five nations are challengers

The economy of this lush, tropical country is now in "high"—revved up by income from oil developments, which exported $644 million bbl in 1953. Iron ore also booms: concessions of U. S. Steel and Bethlehem Steel shipped 3.3 million tons in the first five months of '55. Venezuelan coffers, however, are kept empty by a broadside industrial expansion that currently demands the import of over $5 million in industrial instruments and controls. U. S. leadership in this market is seriously challenged by Germany, Canada, Switzerland, France, and Japan— in that order. Yankee process control equipment made up 75% of the $3.6 million spent to run the continuous-flow plants. But a sizable $¾ million went for electrical power-generating control equipment, and the U. S. got only 25% of that. The types of equipment on the rise indicate the growing sophistication of Venezuelan industry: control valves, timers, motor controls, instrument transformers. Note to manufacturers: there has been a favorable dollar balance for the past 15 years; no government restrictions are on exchange, and customs duties are negligible.

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Improve Your Investment

Last month's editorial urged more emphasis on the engineer's basic investment – training. We advocated study, reading, attendance at technical society meetings, independent research, publication, and teaching. Our thesis is supported by a recent National Industrial Conference Board study on personnel policy, "Tuition-Aid Plans for Employees", just released to associated companies and available through their libraries. Three-quarters of the 166 participating firms offer financial assistance to employees taking courses given by colleges, universities, trade schools, and professional societies. Eighty per cent of these companies are in the same industrial categories as those represented by the bulk of our subscribers: chemical, aircraft, oil refining, electrical and mechanical manufacturing, gas and power, and metal fabrication. Cases detailed in the study show that firms in these groupings have the greatest number of engineers enrolled in courses – yet they report that this number has run an average of only one to five per cent of their total work forces over the past five years. We find this disappointing.

Look over the training opportunities offered by your employer. Half of the companies in the study refund the entire tuition expense. Aid beyond this point varies, but it often includes paying for laboratory fees, books, tools, apparatus, transportation, meals, and, in a few cases, a baby sitter. The companies believe strongly in the benefits of their programs. An aircraft manufacturer employing hundreds of engineers claims that its scheme develops "engineers for future technical management positions, specialists in selected technical fields, and engineers with broader job knowledge". An industrial instrument maker, recognized for its long-established training school for customers' employees, regards its program as a basic part of personnel development. This company holds that the education support plan "aids in preparing employees to do a better job . . . and for advancement". At the same time "it brings promising candidates for promotion to the attention of supervisors".

Here is real incentive and backing, available now – yet how well is it being used? Figures in the study show that the median company outlay encountered for employee education is still only a modest $48 a year. It is obvious that opportunities for investing this way in your career are wide open. Do you take advantage of them?

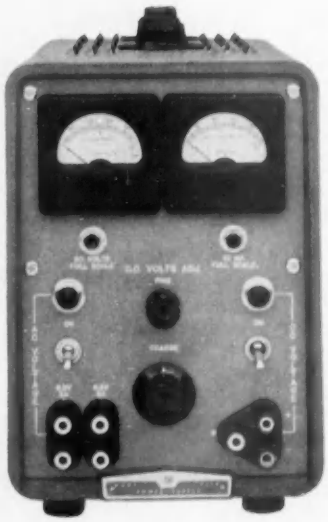
THE EDITORS

why fiddle and fuss?



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High regulation
Current, voltage meters
Overload protection
All-purpose utility



The new -*hp*- 711A was developed to do just one thing—simplify your job of powering all kinds of electronic circuitry in laboratory, field and factory.

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For added convenience, there are separate current and voltage meters with new push-button range switching for accurate measurement of small voltages and currents. Other features include overload protection and grounding on either positive or negative dc terminals. The price is $225.

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Direct or Reverse Controller Actions?

TWO CHARTS SPECIFY SELECTION FOR CASCADE CONTROL

GEORGE PLATT, Scientific Design Co., Inc.
Formerly with Foster Wheeler Corp.

Frequently in designing cascade-connected control systems for a process, the question arises: should individual control elements be arranged for direct action or reverse action? The instrument engineer can decide by tracing the control reaction through each element of the system, but this task is laborious and open to error. Charts containing logical combinations of choices simplify the job.

Direct or Reverse Actions?

Two typical cascade-control problems will be considered in illustrating the use of the charts. In both cases the systems are pneumatic; but the operational principles apply to electric control as well.

In a direct-acting controller, output air pressure increases as the measured variable increases. However, in a reverse-acting controller, output air pressure decreases as the measured variable increases. Output pressure in a direct-acting temperature controller, for example, increases as the temperature increases.

In a direct-acting pneumatic set mechanism an increase in loading pressure from the master controller raises the set-point of the secondary controller. But for reverse action, the set-point is lowered as the loading pressure increases.

Temperature Control System

Consider the cascade-connected temperature control system in Figure 1. Here the controlled process consists of a stream passing through and heated by a gas-fired heater. The (master) temperature controller measures the stream outlet temperature and adjusts the set-point of the (secondary) flow controller accordingly. The flow controller measures the fuel-gas flow, and its output operates the control valve. This valve is assumed to be the usual type in which an air diaphragm motor is opposed by a coil spring.

These questions arise: should the temperature controller be arranged for direct or reverse action? Should the pneumatic set mechanism in the flow controller be arranged for direct or reverse action? And, finally, should the flow controller be arranged for direct or reverse action?

Desired operation of the final control element, the valve, limits freedom of choice in finding answers to these questions. Valve operation depends on what the system is to accomplish. Thus, when measured temperature increases, the valve should close, pass less fuel to the burners, and thereby maintain a constant temperature. Also, when measured flow rises, the valve should close and reduce the flow to keep it constant.

Valve operation in case of failure of the instrument air supply also enters into the problem. When air supply fails at the temperature controller the valve must fail safe by closing and thus cut off the fuel-gas supply to the heater. Air failure at the flow controller should affect the valve in the same way.

Appropriate fail-safe operation of the valve is a construction feature that should be specified at the time of purchase. However, a change in the field, from open on air failure to close on air failure, can be obtained from many valves by reversing body and stem.

To summarize, the valve for the temperature control system should:

- *close* with increase in master variable
- *close* with increase in secondary variable
- *close* with air failure at master controller, and
- *close* with air failure at secondary controller

Chart I shows that the only way this combination of valve operations can be obtained is to have:

- *reverse* action in the temperature controller
- *direct* action in the pneumatic set mechanism, and
- *reverse* action in the flow controller

A step-by-step trace of system operation shows that reverse-direct-reverse gives the correct valve operation. Thus, as temperature increases, the temperature-controller output decreases and the pneumatic set-point is lowered relative to the existing flow (this has the same effect on the flow controller output as if the flow were raised relative to a stationary set-

point). The flow-controller output then decreases and the valve closes. In a similar manner, as the flow increases the flow-controller output decreases and closes the valve.

For air failure at the master controller: the temperature-controller output decreases, the pneumatic set-point drops relative to the existing flow, the flow-controller output decreases, and the valve closes. For air failure at the secondary controller: the flow-controller output fails, and the valve closes.

The above analysis proves two things: reverse-direct-reverse gives the correct valve operation, and the chart arrives at the same answers in a much simpler manner.

Charts I and II contain identical information arranged differently for convenience. For instance, Chart II shows that the reverse-direct-reverse combination selected for the above cascade-connected temperature control system allows two possible types of valve operation: open-open-open-open and close-close-close-close. However, where system operation demands "close on air failure" valve construction, as in the present example, this choice disappears.

Level Control System

Figure 2 shows another common example of cascade-connected control systems. Here the controlled process consists of a liquid stream that enters an accumulator and then flows out. The (master) level controller measures the liquid level and adjusts the set-point of the flow controller. The (secondary) flow controller measures the flow and its output operates the control valve. This control valve should:

- ▶ *open* on high level, and
- ▶ *close* on high flow; and is required to:
- ▶ *close* on air failure at the level controller, and
- ▶ *close* on air failure at the flow controller

Chart I shows these conditions will be met by direct-direct-reverse actions.

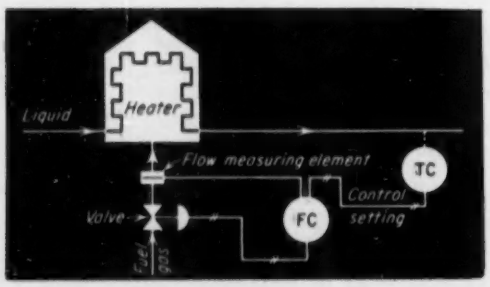
Practical Considerations

But suppose the system operation in Figure 2 calls for the valve to open instead of close on instrument air failure. Chart I shows this open-close-open-open operation requires reverse-reverse-direct actions. Now that reverse pneumatic set is specified, a new problem may arise. Since the so-called conventional (large case) instruments usually have reversible pneumatic set mechanisms, the reverse action is readily obtained in most instances. But miniature instruments do not provide for reverse pneumatic set as a standard feature, although all makes can be furnished with direct pneumatic set and with either direct or reverse controller actions.

CHART 1

SELECT CONTROLLER ACTIONS FROM VALVE POSITIONS

Valve position on increase in		Air failure at		Action of		
Master variable	Secondary variable	Master controller	Secondary controller	Master controller	Pneumatic set	Secondary controller
O	O	O	O	R	D	R
			C	R	D	D
		C	O	D	R	R
			C	D	R	D
	C	O	O	R	R	D
			C	R	R	R
		C	O	D	D	D
			C	D	D	R
C	O	O	O	D	D	R
			C	D	D	D
		C	O	R	R	R
			C	R	R	D
	C	O	O	D	R	D
			C	D	R	R
		C	O	R	D	D
			C	R	D	R



APPLIED TO TEMPERATURE

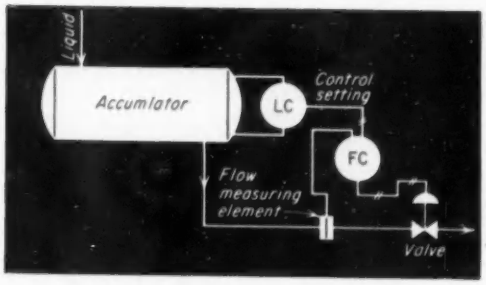
FIG. 1. A cascade-connected temperature control system maintains the liquid stream at some constant temperature. Here the temperature controller measures the stream's output temperature and adjusts the set-point of the flow controller. The controller then opens or closes the valve and allows more or less fuel to be burned in the heater.

CHART 2

SELECT VALVE POSITIONS FROM CONTROLLER ACTIONS

Action of			Valve position on			
			Increase in		Air failure at	
Master controller	Pneumatic set	Secondary controller	Master variable	Secondary variable	Master controller	Secondary controller
D	D	D	O	C	C	O
			C	O	O	C
		R	O	C	C	C
			C	O	O	O
	R	D	O	O	C	C
			C	C	O	O
		R	O	O	C	O
			C	C	O	C
R	D	D	O	O	O	C
			C	C	C	O
		R	O	O	O	O
			C	C	C	C
	R	D	O	C	O	O
			C	O	C	C
		R	O	C	O	C
			C	O	C	O

Code: "O" open, "C" closed, "D" direct, "R" reverse



APPLIED TO LEVEL

FIG. 2. This cascade-connected system maintains constant level through adjustment of the flow controller's set-point by the level controller. Thus any difference between the set-point flow rate and the measured flow rate drives the valve open or closed to maintain the flow demanded by the level controller.

The problem that would exist if an instrument were used that does not allow reverse pneumatic set where it is required can be handled in the following ways: 1) accept the use of direct pneumatic set, or 2) reverse the master controller's output with a reversing relay whose output connects to the secondary-controller pneumatic set mechanism.

The first, though simpler than the second, may be used only if the process can perform properly with the resulting different-from-desired valve operation. Otherwise, the second choice must be used if controller construction permits. However, to avoid additional complications when using a reversing relay, the relay must be tied to the same individual air supply as the secondary controller. Thus the relay and the secondary controller have air supply or air failure simultaneously, and act as an integrated unit.

Although the general rule is that a valve should operate one particular way regardless of the point of air failure within the system, the charts make a distinction between air failure at master and secondary controllers. The distinction applies to systems where separate valve operations are necessary and to other instances where it might conceivably be desired.

The charts apply to direct-connected controllers with direct-acting measuring elements (the systems in Figures 1 and 2), or to direct-acting transmitters with receiver controllers. In most instrument applications, direct-acting measuring elements are used. However, they're also useful with a reverse-acting signal applied to the master controller. Just consider the system as though it were direct acting, determine the appropriate master-controller action from the chart, and actually use the opposite action for the installation. For example, suppose there is a service with a reverse-acting master level transmitter that requires open-close-close-close operation. Chart I, based on all direct measurements, shows that direct-direct-reverse actions should be used. However, since the master transmitter is reverse-acting, its associated control action must actually be reversed. Thus for this system, the correct selection of controller actions is not direct-direct-reverse, but reverse-direct-reverse.

The charts facilitate the choice of proper controller actions for systems generally encountered by instrument engineers. But they do not include the use of reverse-acting secondary transmitters (not usually encountered) nor do they include air-failure conditions at transmitters only. An enlargement of the charts to include all these situations is possible; however, it would complicate them and make them less useful.

How to Find Controller Settings from Process Characteristics

THE GIST: Just how well a process controller performs its job depends on the process characteristics and the corrective actions available in the controller. Frequently, proportional action alone will maintain the required product quality with minimum instrument cost. Some processes may need additional controller actions. Although the cost of the resulting arrangement is somewhat higher, product quality is improved and spoilage significantly reduced.

Of course, the first step is to find out if a proportional controller is adequate, and this means finding the controller settings for optimum performance. Then, if the resulting operation does not meet the requirements, improvement through additional actions should be balanced against additional costs. But remember, maximum performance must be squeezed from each controller action before more actions are considered. In this way, over-instrumenting can be avoided.

Procedures and charts for setting controllers are shown in this article. They simplify the work of determining if a controller, adjusted to its best settings for the process, will do the job. The answers provide adequate information for handling the cost versus performance problem of overall plant operation.

GERALDINE A. COON, Taylor Instrument Cos.

In optimizing controller settings one must consider not only process characteristics but also the type of controller used with the process. Controller actions discussed in this article include proportional, proportional plus reset, and proportional plus rate. A subsequent article covers the adjustment of controllers that combine these actions, namely proportional plus reset plus rate.

CONTROLLER ACTIONS

Table I shows the basic properties of controller actions. If a load change occurs in a closed loop in which the controller has only proportional action, the controlled variable will not return to the set-point. Thus, there is a sustained deviation called offset. An increase in the controller's gain, commonly called proportional gain or proportional sensitivity S, reduces the offset, although the increase must be limited by stability considerations.

If the offset is too great with proportional action only, reset action may be added to the controller. This will eliminate the offset and return the controlled variable to the set-point. It will also decrease the operating frequency (frequency of the damped oscillation seen on the recovery curve), which is undesirable because this indicates slower correction after a disturbance. Usually, with reset action the proportional sensitivity must be reduced in order to maintain the same degree of stability in the controlled system.

Another combination of controller actions consists of rate (or first-derivative) action added to proportional action. Rate action allows a higher proportional sensitivity for the same degree of stability and this may reduce the offset to within allowable tolerances. At the same time rate action considerably increases the operating frequency, which improves the quality of control.

RECOVERY CURVES

How well a controller regulates the process may be judged by the recovery curves that indicate

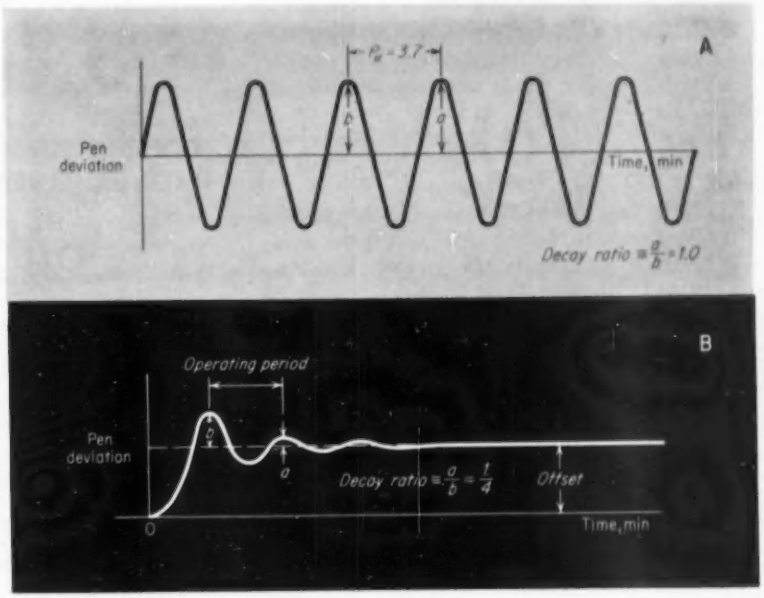


FIG. 1. Figure 1A shows the deviation that results when the controller settings are adjusted to the ultimate values. Here, the oscillation amplitude remains constant with time. Thus, with no decay in the recovery curve, the decay ratio equals unity. But in Figure 1B, the controller has been set for a $\frac{1}{4}$ decay ratio. Now the peak amplitude of each oscillatory cycle is one-fourth the amplitude of the preceding cycle. The recovery curve may reach a steady-state magnitude that differs from the set-point. This difference is called offset.

TABLE I

CONTROLLER ACTIONS

m = change in controller output pressure (psi)
e = actuating signal (inches)
S = proportional sensitivity (psi/inch)
U = reset rate (repeats/minute)
T = rate time (minutes)
f = frequency (cycles/minute)
P_o = operating period (minutes)
p = frequency variable, $j\omega$

Action	Transient response	Frequency response	Transfer function	Typical recovery curve for load change at valve
Proportional	Response to unit step m, S, 0, Time	log gain, 1.0, S, log f Phase, 0°, log f	$\frac{m}{e} = S$	P_o, Pen deviation, Offset, 0, Time
Proportional plus reset	Response to unit step m, Slope = SU, S, 0, Time	log gain, 1.0, S, $\frac{U}{2\pi}$, log f Phase, 0°, -90°, log f	$\frac{m}{e} = S\left(\frac{U}{p} + 1\right)$	P_o, Pen deviation, 0, Time
Proportional plus rate	Response to unit ramp m, T, ST, 0, Time	log gain, 1.0, S, $\frac{2\pi}{T}$, log f Phase, +90°, 0°, log f	$\frac{m}{e} = S(1 + Tp)$	P_o, Pen deviation, 0, Time

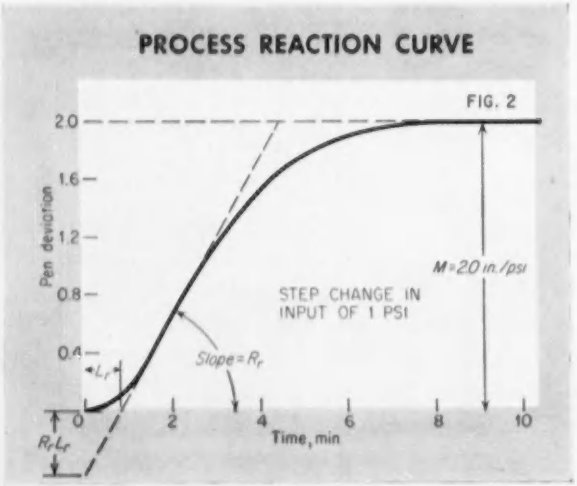
deviations of the controlled variable with respect to time. Good control is evidenced by these desirable features on the recovery curve:

1. The controller and process as an integrated system should be stable. Hunting, or continuous oscillations, where the decay ratio equals unity (Figure 1A), should not exist in the closed-loop system.
2. The offset, or final value of the transient deviation, should be within prescribed tolerances.
3. The recovery time should be rapid. This means that the operating frequency should be sufficiently high.
4. The area away from the final value should not be too large. This property is often used as a measure of the quality of control.

Experience shows that adjusting the controller until a ¼ decay ratio (Figure 1B) appears on the recovery curve after a step change disturbance is a satisfactory compromise between these four requirements. For this reason the ¼ decay ratio will be used as an important criterion for determining good controller settings. Actually, the requirement will be that the fundamental (lowest-frequency) component of the recovery curve have a ¼ decay ratio. In the region of good settings this component is usually dominant.

PROCESS CHARACTERISTICS

In Table I the controller actions were described by showing (1) the response to a step change in input, (2) the frequency response, and (3) the transfer function. The process may also be described in one of these ways, but often process characteristics are not well known or easy to obtain. Yet it is necessary to have adequate information if the control system is to function satisfactorily. The following are some of the ways in which process data may be given:



- reaction curve of the process
- continuous cycling of the closed loop
- frequency response of the process
- analysis of the process

CONTROLLER SETTINGS FROM THE REACTION CURVE

Sometimes it is possible to make a step change in the input to the process and record the process output under open-loop conditions. This output is called the process reaction curve (Figure 2). The curve is analyzed by drawing a straight line tangent to the steepest portion of the curve. The reaction rate, R_r, is the slope of this line divided by the magnitude of the step change; the time intercept, L_r, is called the effective lag. Once these quantities are known, one may use the Ziegler-Nichols formulas for setting the proportional sensitivity S and reset rate U. For good control they recommend:

Proportional action

$$S = 1.0/R_r L_r$$

Proportional-plus-reset actions

$$S = 0.9/R_r L_r, \qquad U = 0.3/L_r$$

The reaction curve shown on Figure 2 was obtained by making a step change of 1.0 psi. The vertical intercept R_rL_r is 0.44 in./psi and the effective lag L_r is 0.80 min. According to the formulas the controller adjustments are:

Proportional action

$$S = 1.0/0.44 = 2.3 \text{ psi/in.}$$

Proportional-plus-reset actions

$$S = 0.9/0.44 = 2.0 \text{ psi/in.}$$

$$U = 0.3/0.8 = 0.38 \text{ repeats per min}$$

The quality of control usually ranges from fair to good when either type of controller is adjusted in the manner indicated above. But an objection to this method is that it does not give much additional information about the recovery curve, such as the operating frequency or the degree of stability in the system (decay ratio).

Obtaining a process reaction curve is easy, takes little time, and requires little special equipment. In many cases, however, it is not practical to do this since the disturbance would produce intolerable upsets in the system.

CONTROLLER SETTINGS FROM CLOSED-LOOP CYCLING

Some information may be obtained about the process itself under closed-loop conditions. The reset rate and the rate time are both set at zero and then the proportional sensitivity is adjusted until continuous cycling occurs in the closed loop (Figure 1A). This setting is the ultimate proportional sensitivity S_u. From the graph one can find the ultimate period, P_u, or ultimate frequency $f_u = 1/P_u$. Knowing the

ultimate values of sensitivity and period, Ziegler and Nichols suggested the following rules of thumb for obtaining good controller settings:

Proportional action

$$S = 0.5\,S_u$$

Proportional-plus-reset actions

$$S = 0.45\,S_u$$

$$U = 1.2/P_u = 1.2\,f_u$$

Figure 1A shows the closed-loop cycling for the process used in the example above. In this case the ultimate sensitivity $S_u = 4.0$ psi/in. and the ultimate period $P_u = 3.7$ min. By this method the controller adjustments are:

Proportional action

$$S = 0.5\ (4.0) = 2.0 \text{ psi/in.}$$

Proportional-plus-reset action

$$S = 0.45\ (4.0) = 1.8 \text{ psi/in.}$$

$$U = 1.2/3.7 = 0.32 \text{ repeats per min}$$

These settings agree very well with those based on the process reaction curve.

Since the settings depend on the proportional sensitivity and frequency which were found experimentally, one should be certain that these are really ultimate values. Increasing the sensitivity slightly above the ultimate value should result in an oscillation of increasing amplitude. It may not be possible to do this in practice, since the process may run out of control before the sensitivity can be reduced.

CONTROLLER SETTINGS FROM THE FREQUENCY RESPONSE

There are numerous ways in which controller adjustments can be selected on the basis of frequency response. Only a few will be discussed here, with emphasis on the method of ¼ decay ratio.

Continuous Cycling of the Closed Loop

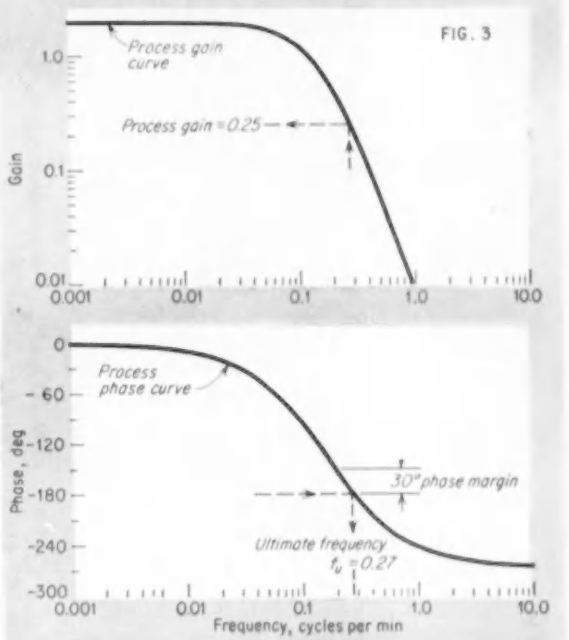
The process frequency response may be obtained either by experimental tests or by direct calculation. It is possible to find the quantities f_u and S_u directly from this and then to substitute in the formulas given above for controller settings. The ultimate frequency f_u is the frequency at which the process phase lag is 180 deg. The ultimate sensitivity S_u equals unity divided by the process gain at the frequency f_u. For example Figure 3 shows that $f_u = 0.27$ cpm; the corresponding value of process gain is 0.25 in./psi so that $S_u = 1.0/0.25 = 4.0$ psi/in.

30-Deg Phase Margin

A rule commonly used in design work provides a margin of stability in the closed loop. This is that the phase margin should be at least 30 deg in order for the system to perform satisfactorily. To obtain a phase margin of 30 deg, the phase lag of the open loop must be 150 deg when the open-loop gain is unity. If proportional action only is being used, it contributes no phase lag to the loop and the phase margin will be 30 deg when the process phase lag is 150 deg. In the example of Figure 3 this occurs at the frequency 0.19 cpm. This frequency is significant, for it is usually about the same as the operating frequency. At this frequency the process gain is 0.51 in./psi and the open-loop gain will be unity if the controller sensitivity is adjusted to $S = 1.0/0.51 = 2.0$ psi/in. This setting, which is easy to calculate for a proportional controller, usually results in satisfactory performance and at the same time insures stability in the closed loop.

PROCESS FREQUENCY RESPONSE

FIG. 3

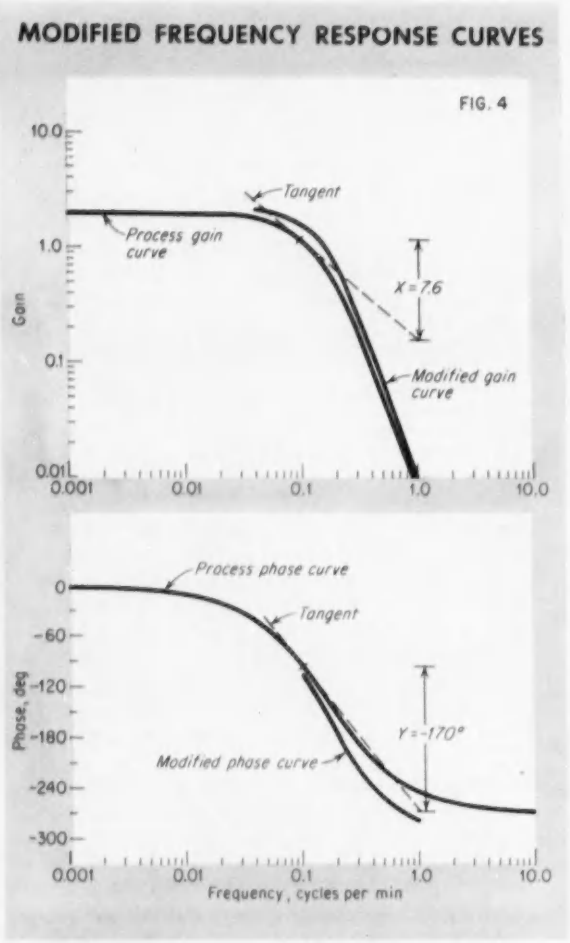


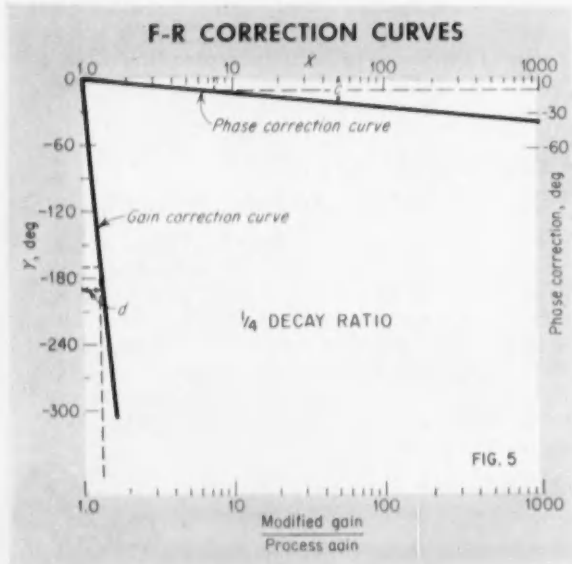
CONTROLLER SETTINGS FOR 1/4 DECAY RATIO

From the frequency response it is also possible to find controller settings that will give a decay ratio of ¼ in the recovery curve. In addition to giving satisfactory controller settings, this method also indicates the operating frequency and degree of stability (¼ decay ratio) of the recovery curve. No further calculations are needed to make fairly accurate predictions about the shape of the closed-loop transient response.

Modifying the Frequency Response

In this method graphical corrections are applied to the process frequency-response curves. The modi-





fied curves are then used in calculating controller settings. The correction to the gain curve at any frequency depends on the slope of the phase curve at the same frequency, the correction being positive when the slope of the phase curve is negative. The correction to the phase curve depends on the slope of the gain curve, the correction being negative when the slope of the gain curve is negative.

A graphical procedure for obtaining corrections to the process frequency response will now be shown, using Figures 4 and 5. To correct the gain at the frequency 0.1 cpm:

1. Draw the tangent to the phase curve at the frequency 0.1 cpm.

2. Calculate Y, which is the number of degrees change in the tangent to the phase curve over one decade on the frequency scale. Thus Y = (−265 deg) − (−95 deg) = −170 deg.

3. On Figure 5 locate the point Y = −170 deg on the left-hand vertical axis. The corresponding point on the lower horizontal axis is 1.32, which is the ratio of the modified gain to the process gain. Since the process gain at $f = 0.1$ cpm is 1.18 in./psi, the modified gain is (1.32) (1.18) = 1.56 in./psi. This value is plotted on Figure 4 at $f = 0.1$ cpm.

If the same scales are used on Figures 4 and 5, steps 2 and 3 may be done with a pair of dividers without making any readings. It is not even necessary to do the multiplication since the gain is plotted on a log scale.

This graphical procedure will be illustrated by finding the gain correction at $f = 0.2$ cpm. A straight line is drawn tangent to the phase curve at $f = 0.2$ cpm. The change in the tangent over one decade, Y, is measured with a pair of dividers and laid off on the Y-scale of Figure 5 (Y = −190 deg). Measure the distance d with a pair of dividers and lay this distance off above the process-gain curve (Figure 4) at $f = 0.2$ cpm. This gives a second point on the modified gain curve. In a similar manner other points are located at $f = 0.5$ cpm and $f = 1.0$ cpm.

In order to correct the process-phase curve, a tangent is drawn to the gain curve at the frequency under consideration, say, $f = 0.1$ cpm. The next step is to find X, which is the change in gain on the tangent to the gain curve over one decade on the frequency scale. At $f = 0.1$ cpm, X = 1.18/0.155 = 7.6 Once X is known, the phase correction is found from Figure 5, which may be used for any process. In this case the phase correction is minus 11 deg. Since the process phase at this frequency is minus 95 deg, the modified phase is (−95 deg) + (−11 deg) = −106 deg at $f = 0.1$ cpm (Figure 4).

Since Figures 4 and 5 have the same scales, the correction may be made by using a pair of dividers. After drawing the tangent to the gain curve at some frequency, say $f = 0.2$ cpm, one measures X with a pair of dividers. This distance (corresponding to

$X = 50$) is laid off on the X-scale to the right of the point $X = 1.0$ on Figure 5. Measure the distance c and lay it off below the process phase curve (Figure 4) at $f = 0.2$ cpm. In this way points on the modified phase curve may be located quickly without making any readings or calculations.

The curves of Figure 5 apply to any type of frequency response paper. If the correction curves are plotted on the same scales as the process frequency response, then points on the modified curves may be located without making any calculations whatever. The work is further shortened since the modified curves are used only in the vicinity of 180-deg phase lag.

Some approximations are involved in this method. It is assumed that the recovery curve is dominated by a single damped oscillation and that the curvature of the gain and phase curves is not too great. However, this method has worked well in a large number of cases.

Proportional Action

The procedure for setting a proportional controller so that the recovery curve will have a decay ratio of ¼ is the following:

1. Determine the frequency f_o at which the phase lag of the modified process curve is 180 deg. This is the operating frequency, which for the example given is $f_o = 0.2$ cpm.

2. Read the modified gain g_o at the frequency f_o. On Figure 4, $g_o = 0.66$ in./psi.

3. The proportional sensitivity setting is $S = 1.0/g_o$. For the process under consideration $S = 1.0/0.66 = 1.5$ psi/in.

Earlier the frequency response was used to show that continuous cycling would exist in the closed loop if the sensitivity were set at 4.0 psi/in. and that the ultimate frequency would be 0.27 cpm. To obtain ¼ decay ratio in the recovery curve, it is necessary to reduce the proportional sensitivity to 1.5 psi/in. The operating frequency will then be 0.2 cpm. Thus, this method gives the operating frequency and also the degree of stability (¼ decay ratio) of the recovery curve.

Proportional-Plus-Reset Action

When reset action is added to the controller, it is necessary to specify another condition in addition to ¼ decay ratio. Some workers in the field have obtained good results by setting the reset rate equal to the operating frequency. In the following procedure a proportional-plus-reset controller is adjusted so that the recovery curve has a ¼ decay ratio and the reset rate equals the operating frequency:

1. Determine the frequency f_o at which the modified phase lag of the process is 171 deg. This is the operating frequency — for the process of Figure 4, $f_o = 0.19$ cpm.

2. Read the modified process gain g_o at the frequency f_o; in this case $g_o = 0.75$ in./psi.

3. The settings are:

$$S = \frac{1.0}{g_o} \qquad U = f_o$$

In the example, then

$$S = 1.0/0.75 = 1.3 \text{ psi/in.}$$
$$U = 0.19 \text{ repeats per min}$$

In adding reset action to a proportional controller, it is necessary to reduce the proportional sensitivity from 1.5 to 1.3 psi/in. in order to keep the same decay ratio. At the same time reset action has decreased the operating frequency from 0.2 cpm to 0.19 cpm, which means that the period of the recovery curve is increased slightly.

Proportional-Plus-Rate Action

Table I shows the frequency response of a proportional-plus-rate controller which has unlimited gain and 90-deg phase lead at high frequencies. A commercial controller does not exhibit this idealized type of behavior. However, if the controller can be described by the idealized frequency response up to frequencies where the phase lead is 60 deg, then the results of this section will apply.

Although the adjustment of a proportional-plus-rate controller has not been discussed up to this point, numerous methods exist for doing this. In choosing controller settings it is reasonable to require that the recovery curve have a ¼ decay ratio and also the smallest possible offset. This means that the proportional sensitivity should be as high as possible while maintaining ¼ decay ratio.

The benefits of rate action are due mainly to the fact that it introduces a phase lead (dependent on rate time T) into the controller. Essentially, the following procedure tries controller modified phase leads of 0, 30, and 60 deg to find the combination of settings that gives the highest proportional sensitivity. Of course, a phase lead of 0 deg means that the rate time T is 0 so that the controller has only proportional action.

1. Find the frequency f_o at which the modified phase lag is 180 deg. Read the modified process gain g_o at f_o. Then

$$S = 1.0/g_o, \quad T = 0 \qquad \text{(0 deg phase lead)}$$

As in the case of proportional action, $f_o = 0.2$ cpm, $g_o = 0.66$ in./psi, $S = 1.5$ psi/in., and $T = 0$ min.

2. Find the frequency f_o at which the modified phase lag is 210 deg. Read the modified gain g_o at this frequency.

Then

$$S = 1.0/g_o, \quad T = 0.084/f_o \qquad \text{(30 deg phase lead)}$$

In the example $f_o = 0.28$ cpm, $g_o = 0.33$ in./psi and

$$S = 1.0/0.33 = 3.0 \text{ psi/in.} \quad T = 0.084/0.28 = 0.3 \text{ min}$$

3. Find the frequency f_o at which the modified phase lag of the process is 240 deg. Read the modified process gain g_o at f_o. Then

$$S = 0.69/g_o, \quad T = 0.20/f_o \qquad \text{(60 deg phase lead)}$$

WHERE RATE ACTION IMPROVES CONTROL

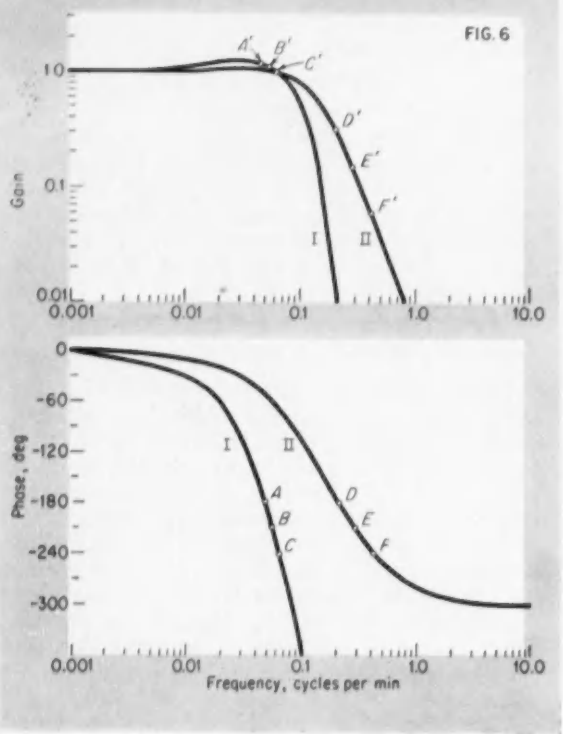


TABLE II SEE FIGURE 6

	Operating Frequency cpm f_o	Process Gain in/psi g_o	Proportional Sensitivity psi/in S	Rate Time min T
PROCESS I				
Proportional (0° Phase Lead)	0.048	1.15	0.87	0
Prop. + Rate (30° Phase Lead)	0.056	1.12	0.89	1.5
Prop. + Rate (60° Phase Lead)	0.064	1.02	0.68	3.1
PROCESS II				
Proportional (0° Phase Lead)	0.21	0.31	3.2	0
Prop. + Rate (30° Phase Lead)	0.29	0.15	6.7	0.29
Prop. + Rate (60° Phase Lead)	0.42	0.060	11.5	0.48

For the process under consideration $f_o = 0.41$ cpm, $g_o = 0.11$ in./psi, so that

$S = 0.69/0.11 = 6.3$ psi/in., $T = 0.20/0.41 = 0.49$ min

4. Choose the combination of settings which gives the largest value of S, thus giving the smallest offset. In the example, this is the combination $S = 6.3$ psi/in. and $T = 0.49$ min. If the controller is adjusted in this manner, the recovery curve will have a ¼ decay ratio and an operating frequency of 0.41 cpm.

It may be noted that the addition of rate action to a proportional controller has allowed an increase in proportional sensitivity from 1.5 to 6.3, thus reducing the offset by a factor of about 4. Furthermore, the recovery time has been shortened since the operating frequency has increased from 0.2 to 0.41 cpm. These results are verified by the curves on Figure 7A, which were computed with these settings.

RATE ACTION IMPROVES CONTROL

Frequency-response plots of a process tell whether or not the addition of rate action to the controller will make a significant improvement in the regulation of the process. To illustrate, two different processes (Figure 6) will be compared.

Consider the modified process curves labeled I in this figure. Table II, which was computed from the formulas given above, shows the frequency f_o, process gain g_o, controller sensitivity S, and rate time T, that result with proportional control only, proportional-plus-30-deg phase lead, and proportional-plus-60-deg lead. Here, the controller sensitivity increases slightly with 30-deg phase lead as compared with proportional action only. And when 60-deg phase lead is used the sensitivity decreases somewhat.

But this same table shows that adding rate action to Process II considerably improves the quality of control. Here, the addition of 60-deg phase lead from rate action doubles the frequency and increases the sensitivity by a factor of 3.6 over proportional control only.

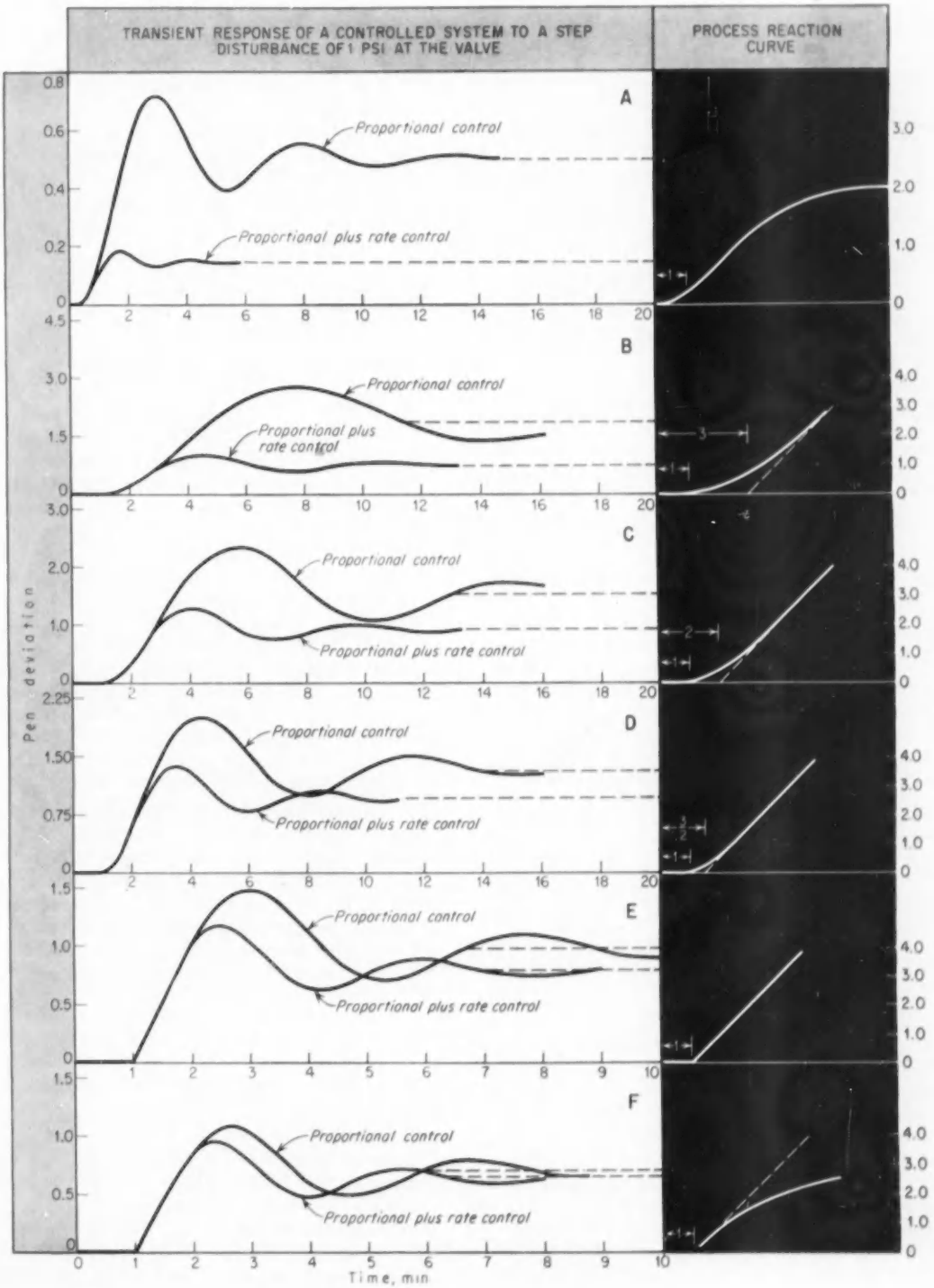
The foregoing results can be summarized in these rules that tell, from the f-r plots of the process, whether or not rate action will improve the process's control:

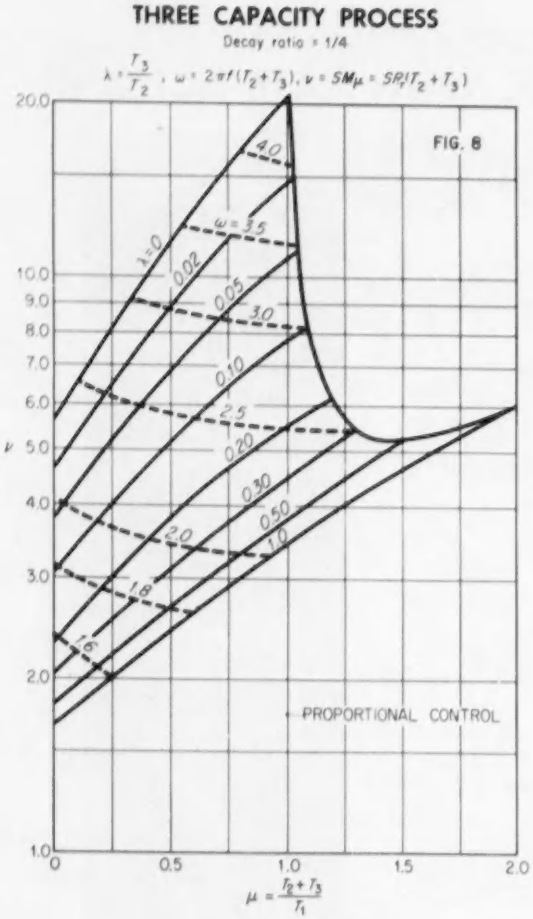
1. If the process phase-angle characteristic has a steep slope in the vicinity of 180-deg lag (as in Process I) the frequency is not changed much by an additional 30- or 60-deg lead from the controller. Furthermore, the process gain remains about the same in this range of frequencies, so that the controller gain (hence sensitivity) remains about the same. Therefore, processes with this f-r characteristic will not be significantly improved by the addition of rate action.

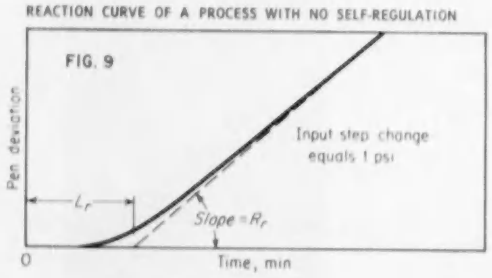
2. However, if the phase curve changes gradually near the minus-180-deg point, as in Process II, a 30- or 60-deg phase lead increases the frequency consider-

FIG. 7.

IMPROVE CONTROL WITH RATE ACTION







ably. And in this range of frequencies the process gain has a large negative slope, so that the controller gain, and therefore sensitivity, increase greatly as the frequency increases. This increased sensitivity due to rate action reduces the offset following a disturbance.

Figure 7 shows the transient responses of some processes that have been subjected to a step disturbance of 1 psi at the valve (final control element). For each of several processes, as characterized by their reaction curves, the recovery with and without rate action is shown. In all cases the controller settings give ¼ decay ratio for proportional control and ¼ decay ratio and minimum offset for proportional-plus-rate action. Some processes show more improvement in control than others after rate action is added to proportional action, although rate action makes at least a slight improvement in every case.

Summarizing the effects of rate action on the processes considered in Figure 7 develops these general rules:

- rate action improves control if the distance-velocity lag is small compared to the effective lag
- rate action has more effect on processes without self-regulation than on those with self-regulation
- rate action greatly improves the control of pure two- and three-capacity processes.

CONTROL CHARTS FOR PROPORTIONAL ACTION

Sometimes by analytical methods[1] it is possible to find the process characteristics: the time constants $T_1, T_2, T_3, \ldots\ldots$, the distance-velocity lag L and the process sensitivity (M of Figure 2). For convenience, T_1 is taken to be the largest time constant, T_2 the next largest, etc. Knowing these characteristics, one might proceed to calculate the process-reaction curve or frequency response and then find controller settings by one of the above methods.

For a number of processes, however, much of the tedious work has been eliminated by the use of control charts. These charts, which were developed by Ziegler and Nichols, tell how to adjust a proportional controller so that the recovery curve will have a ¼ decay ratio. They also give the operating frequency. An example will serve to illustrate their use.

Three-Capacity Process

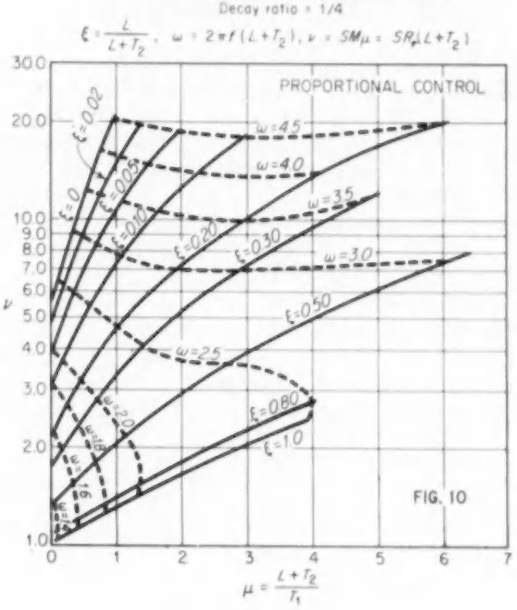
The reaction curve of Figure 2 and the frequency response of Figure 3 were drawn for a process having three noninteracting time constants: $T_1 = 1$ min, $T_2 = 1$ min, $T_3 = 1$ min, and a process sensitivity $M = 2$ in./psi. Such a process is called a "three-capacity process". To enter Figure 8, which is the appropriate control chart, the dimensionless process characteristics μ and λ must be calculated:

$$\mu = \frac{T_2 + T_3}{T_1} = \frac{1.0 + 1.0}{1.0} = 2.0$$

$$\lambda = \frac{T_3}{T_2} = \frac{1.0}{1.0} = 1.0$$

On the horizontal scale locate the point $\mu = 2.0$ and proceed vertically to the solid contour $\lambda = 1.0$. Opposite this point on the vertical scale read the dimensionless-sensitivity setting $\nu = 6.0$. The dimensionless frequency ω (dashed contour) is about 2.6 at the point $\mu = 2.0$ and $\lambda = 1.0$. From these values the actual proportional sensitivity S and frequency f can be calculated, using the formulas on the figure:

TWO CAPACITY PROCESS WITH DISTANCE-VELOCITY LAG



$$S = \frac{\nu}{M\mu} = \frac{6.0}{(2)(2)} = 1.5 \text{ psi/in.}$$

$$f = \frac{\omega}{2\pi(T_2 + T_3)} = \frac{2.6}{2(3.14)\ (2.0)} = 0.21 \text{ cpm}$$

Thus, if the proportional sensitivity is adjusted to 1.5 psi/in., the closed loop will oscillate with a $\frac{1}{4}$ decay ratio, the operating frequency being 0.21 cpm. These are precisely the values found earlier by the method of $\frac{1}{4}$ decay ratio.

What would happen if the process time constants were doubled ($T_1 = 2$ min, $T_2 = 2$ min and $T_3 = 2$ min) and the process sensitivity M left unchanged? The values of μ and λ would remain the same so that again $\nu = 6.0$ and $\omega = 2.6$. The calculations show that the proportional sensitivity would still be set at 1.5 psi/in. but the operating frequency would be cut in half.

Other special processes are included on this graph. For a pure two-capacity process, $T_3 = 0$ so that $\lambda = T_3/T_2 = 0$. Hence, all pure two-capacity processes are located on the contour $\lambda = 0$. If the process were characterized by two noninteracting time constants, $T_1 = 1$ min, $T_2 = 1$ min, and a process sensitivity $M = 2$ in./psi, then

$$\mu = \frac{T_2 + T_3}{T_1} = \frac{1.0 + 0}{1.0} = 1.0$$

$$\lambda = \frac{T_3}{T_2} = 0$$

From the control chart $\nu = 20.5$ and ω appears to be about 4.5. Thus

$$S = \frac{\nu}{M\mu} = \frac{20.5}{(2)\ (1)} = 10 \text{ psi/in.}$$

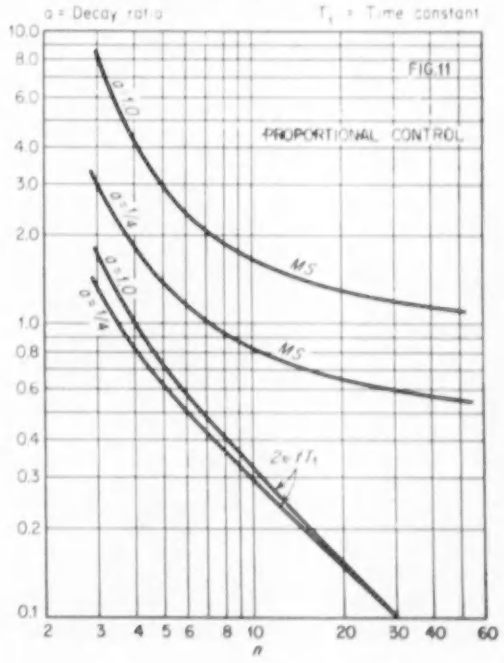
$$f = \frac{\omega}{2\pi\ (T_2 + T_3)} = \frac{4.5}{2(3.14)\ (1.0 + 0)} = 0.72 \text{ cpm}$$

By reducing the number of equal time constants in the process from 3 to 2, the proportional sensitivity can be increased from 1.5 to 10, which means that the offset is decreased in this same ratio. At the same time the operating frequency is increased from 0.21 to 0.72, a significant improvement in recovery time. In both cases the same degree of stability ($\frac{1}{4}$ decay ratio) is maintained in the closed loop.

If the process-reaction curve does not level off at any finite value (Figure 9), then the process is said to have no self-regulation and it is characterized by a reaction rate R_r. In this case the largest time constant is infinite, so that $\mu = (T_2 + T_3)/T_1 = 0$. Thus, all processes having three noninteracting capacities and no self-regulation are located on the vertical axis.

For example, consider a process without self-regulation, having time constants $T_2 = 1$ min and $T_3 = 1$ min. The reaction rate is 0.5 (in.)/(min)(psi). This is a three-capacity process, since there are two finite time constants and one infinite one.

PROCESS WITH n EQUAL CAPACITIES



$$\mu = \frac{T_2 + T_3}{T_1} = 0$$

$$\lambda = \frac{T_3}{T_2} = 1.0$$

From the control chart $\nu = 1.6$ and ω is about equal to 1.4. On using the alternative formula for ν given in Figure 8, one finds

$$S = \frac{\nu}{R_r (T_2 + T_3)} = \frac{1.6}{0.5(2.0)} = 1.6 \text{ psi/in.}$$

$$f = \frac{\omega}{2\pi(T_2 + T_3)} = \frac{1.4}{2(3.14)\ (2.0)} = 0.11 \text{ cpm}$$

Two-Capacity Process with Distance-Velocity Lag

This question often arises in the design of a process: is it more advantageous to reduce the distance-velocity lag or to reduce the time constants for improved process control? The control chart of Figure 10 helps to answer this question for a process with two time constants and a distance-velocity lag. Here, two dimensionless parameters, μ and ξ, describe the process characteristics. The dimensionless sensitivity ν is plotted on the vertical axis.

Suppose that a particular process has these actual characteristics:

$L = 1$ min, $T_1 = 10$ min, $T_2 = 1$ min and $M = 1$ in./psi

The control chart of Figure 10 helps determine whether more benefit is gained by reducing L, T_2, or T_1.

For this process, as found from Figure 10,

$\mu = (L + T_2)/T_1 = (1 + 1)/10 = 0.2$

$\xi = L/(L + T_2) = 1/(1 + 1) = 0.5$

Then, from Figure 10, $\nu = 1.45$ and $\omega = 1.50$. Thus,

$S = \nu/M\mu = 1.45/0.2 = 7.2$ psi/in.

$f = \omega/2\pi(L + T_2) = 1.5/4\pi = 0.12$ cpm

Now suppose T_1 is reduced so that $T_1 = T_2 = L = 1.0$ min. Performing the above calculations after finding the appropriate values of ν and ω from the chart yields a proportional sensitivity of 1.4 psi/in. and a frequency of 0.18 cpm. Thus, reducing T_1 is bad for control because sensitivity has been reduced from 7.2 to 1.4.

A second trial reduces the smaller time constant T_2 from 1.0 min to 0.1 min while keeping $L = 1$ min and $T_1 = 10$ min. This improves sensitivity somewhat, the new value being 10 psi/in.

Finally, if the distance-velocity lag is reduced to 0.1 min and the other characteristics remain at their original values, the resulting sensitivity increases to 32 psi/in. and the operating frequency to 0.27 cpm. This means that the reduction in the distance-velocity lag increases the proportional sensitivity by a factor of 4.5 while maintaining the same stability in the recovery curve.

The above analysis shows that reduction of the distance-velocity lag makes the greatest improvement in control. It is also desirable to reduce the smaller, but not the larger, time constant. These conclusions are rules of thumb which apply to many other types of processes.

One-Capacity Process with Distance-Velocity Lag

The control chart of Figure 10 also includes the type of process for which T_2 equals zero. The dimensionless sensitivity ν is found from $\mu = L/T_1$ as read along the $\xi = 1.0$ curve.

Analysis of this curve and its associated equations indicates again that excessive distance-velocity lags adversely affect process control. Performance is somewhat analogous to that of the two-capacity process with distance-velocity lag.

n-Equal Capacity Process

Some processes contain several noninteracting equal capacities; a fractionating column is a possible example. For this type of process the control chart of Figure 11 gives a good setting for a proportional controller. The two upper curves show the product of process sensitivity and controller sensitivity, at decay ratios of unity and $\frac{1}{4}$, depending upon the number of equal time constants n. The two lower curves show the corresponding operating frequencies. For small values of n the addition of another time constant produces a pronounced drop in sensitivity and also in frequency. For large values of n the sensitivity does not change much if another capacity is added.

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Consider Using HYBRID AMPLIFIERS

A new technique is being used in automatic control—the hybrid amplifier. It's based partly on elements and components just recently developed—germanium, silicon, and selenium diodes; tantalum electrolytics; germanium and silicon transistors; and magnetic toroids wound on cores with rectangular flux-current loops—and partly on older amplification methods involving the vacuum-tube amplifier with its associated components. This combination of old and new widens the application area for control amplifiers, and permits new levels of performance, reliability, and miniaturization. The following outlines the system characteristics of a few of these hybrids.

GEORGE M. ATTURA, Industrial Control Co.

Two problems created the need for hybrid amplifiers: the limited reliability and power supply capabilities of all-tube amplifiers, and the limited gain and performance possible with even the best magnetic amplifiers. The obvious limitations of the all-tube amplifier in complex systems provided the impetus to development of magnetic circuits to replace the tube in control applications. The bulk of the new program was directed toward the problems of stage gain, speed of response, null-point drift, stability with line power and environmental changes, and circuit miniaturization. The control engineer's aim, however, remained to achieve the circuit performance of the tube amplifier. This is understandable, since much control art developed around the tube amplifier, and most available control components are designed to mate with tube-circuit packages. While the overriding virtue of a well-designed, all-magnetic circuit is its reliability, it cannot compare with the tube amplifier in stage gain, bandwidth, high input impedance, and low-level operation. The need for complete reliability may point to a magnetic circuit, but the control engineer may be loath to sacrifice the degree of system performance he has become accustomed to through his experience with tube-circuit packages.

There are two reasons for the difference in performance between the vacuum-tube amplifier and the magnetic circuit. A magnetic amplifier is controlled through the flux level in a core, resetting it from its saturated value to some initial flux density

HYBRIDS ARE FORMED BY COMBINING THESE SIGNAL AMPLIFIERS

VACUUM TUBES

Most widespread use, highly developed circuitry, appreciable dissipation per stage, reliability acceptable only with premium tubes and derated circuits, high stage gain.

TRANSISTORS

Recent development, manufacturing techniques not fully stabilized, circuitry under intense development, good reliability with best transistors available, low dissipation, moderate stage gain.

MAGNETIC AMPLIFIERS

High-speed circuits, core materials and components well developed, good reliability possible, stage dissipation high in many circuit configurations, low stage gain.

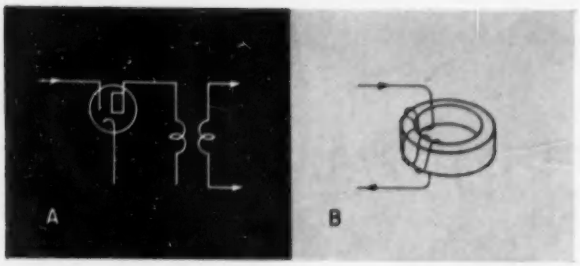


FIG. 1. Amplifiers: A, vacuum-tube, and B, magnetic. In vacuum-tube unit, control signal into negative grid sees very high impedance; power absorption is low. In magnetic amplifier, control signal must supply power to control coil to change flux level during reset.

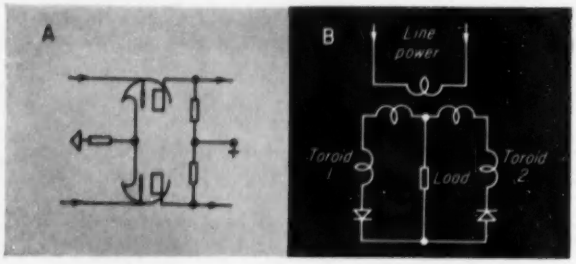


FIG. 2. Differential amplifiers: A, vacuum-tube, and B, magnetic.

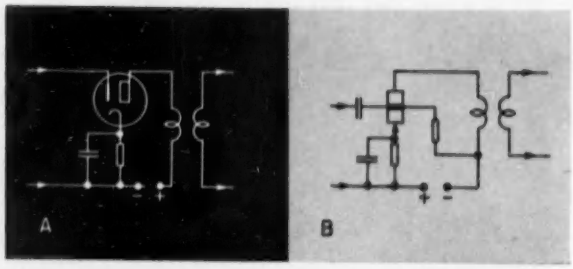


FIG. 3. Single-ended, reversible amplifiers; A, vacuum-tube, and B, transistor.

as required to give the desired load action. This change of flux requires electrical power from the control circuit or driver, the power (or energy per half-cycle of line voltage) being proportional to the area under the flux-current loop of the material, and to the weight of the core. Theoretically at least, it is possible to design a toroid wound on a very small diameter core using wire of such a small cross-sectional area that a large number of turns can be accommodated. However, practical limitations to core diameter and wire size are dictated by manufacturing difficulties and winding problems. These effectively limit the inside diameter of usable cores to about ½ in. and discourage the use of wire finer than #44 gage. The net result is that even the most sophisticated magnetic circuits require a control power level much greater than that necessary to drive the grid of a vacuum tube, Figure 1. Thus the magnetic amplifier has low power gain and input impedance compared to a vacuum-tube amplifier.

The second problem, the null-point stability of the magnetic amplifier, is concerned with how the signal is carried in the circuit. The reversible magnetic amplifier can be considered a balanced or differential amplifier, Figure 2, in which signal intelligence is carried as the difference in level between two separate sections. This technique is similar to that used in double-triode differential dc amplifiers. Here, as in the vacuum-tube circuit, are the problems of carefully balancing and stabilizing the independent transfer characteristics of each section, and requiring that both sections track over a limited range. But like the double-triode amplifier, these requirements can never be completely satisfied, and, regardless of the precautions taken, the null point of the amplifier will drift with line voltage and frequency, temperature, and component aging.

The designer must either accept these basic limitations of the all-magnetic circuit structure or cast about for some fresh approach. One answer lies in the hybrid amplifier, combining the magnetic output stage with a transistor or premium vacuum-tube bi-directional amplifier, Figure 3. This combination has the sensitivity and performance of the transistor or vacuum tube and the efficiency of the magnetic output stage. Complex characteristics can be obtained from control circuits that are capable of reliable operation over a wide environmental range, can be packaged in miniature enclosures, and will operate directly from the ac line with high efficiency. And sometimes circuit characteristics surpass even those of all-tube amplifiers.

But the big question is reliability. These combinations cannot be considered if the transistor or vacuum tube is a weak link, with a circuit life so poor that it rules out all other advantages.

The transistor offers the best chance for a hybrid circuit with an overall reliability equal to that of the magnetic output stage alone. Although there were production problems in the early stages, a well-made germanium or silicon transistor, operated in a controlled environment, is fully as reliable a physical device as a core and coil, and potentially more reliable than a fabricated multi-plate selenium rectifier, a common component of magnetic amplifiers. There is every indication that within a short time transistors will be available with indefinite shelf and operating lives; at the moment, in fact, several manufacturers have available transistors that can be expected to operate many thousands of hours without maintenance or replacement.

With vacuum tubes, the situation is somewhat similar. Most reliability reports on vacuum tubes deal with equipment in which many tubes, designed primarily for the radio industry, are cascaded to

perform some complex function, and here the equipment failure rate is not that of one single tube, but involves the statistical probability of one of very many going bad. Also, the power output and rectifier stages carry high voltages and currents and thus dissipate large amounts of power in the tubes. The attendant heat rise is generally the greatest single cause of failure.

This suggests that if premium tubes are used in small numbers, and their function is limited to low-level, low-plate-dissipation amplifiers, good equipment reliability can be expected. This is exactly the situation—and the result—in a hybrid amplifier. The power output stage is magnetic, and the tube operates at low plate dissipation with low temperature rise. Also, fewer tubes are necessary. A typical tube servo amplifier might have two power output tubes, one rectifier, and two voltage amplifiers; a total of five, with three of these operating at high dissipation levels. Its hybrid equivalent consists of one low-level tube and a magnetic output stage. The reliability of this combination is several orders of magnitude better than that of the all-tube circuit. Premium tubes are available today with expected operating lives of 5,000 to 10,000 hours and with overall performance and reliability that warrant their inclusion in limited number in magnetic-amplifier hybrids.

The following sections discuss typical hybrid amplifiers for five different types of applications. Some of the units possess characteristics that cannot be duplicated with other types of amplifiers. Thus in certain instances, the hybrid magnetic circuit emerges not just as a replacement for an all-vacuum-tube amplifier, but as a means of achieving a degree of miniaturization, performance, or efficiency hitherto impossible. The miniaturization that is possible with hybrid amplifiers is particularly important in airborne applications.

INSTRUMENT SERVO AMPLIFIERS

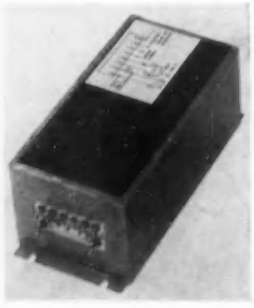
Probably the largest single application of magnetic circuits today is in instrument servos. These positional or velocity servo systems drive a load whose mechanical power requirements are below a few watts. In many cases, because the reflected load to the motor is negligible, for all practical purposes the motor is running free. The motors are usually two-phase, low-inertia units, with straight-line torque-speed characteristics.

Figure 4A shows a miniaturized transistor-magnetic 400-cps amplifier used for driving the BuOrd MK 14 and MK 7 servo motors. Overall dimensions are 2 x 1 21/32 x 4 $\frac{3}{4}$ in., with a weight of 18 oz. Figure 4B shows the loop interconnections. Notice that only six connections are necessary: two for input, two for output, and two for 117 volts, 400 cps. The amplifier draws raw power from the line and meters it to the servo motor in accordance with the error signal. No power supply is required, and line voltage and frequency need not be regulated. The internal temperature rise is only a few degrees centigrade, and all components are protected by encapsulation in resin and by the sealed metal can. The power gain of 3×10^6 is adequate for most synchros or potentiometer servos of this type, and the output zero does not shift with temperature, voltage, or frequency. This hybrid amplifier has these advantages over all-vacuum-tube, transistor, and magnetic amplifiers:

- no need for the power supply required in vacuum-tube or transistor output stages
- internal temperatures low: dissipation in the output stages low compared with vacuum-tube or transistor amplifiers
- smaller and lighter than comparable vacuum-tube and magnetic amplifiers
- none of the zero drift usually encountered in cascaded magnetic amplifiers
- faster response than cascaded magnetic amplifiers
- fewer wires in the system harness

Figure 5 shows a similar amplifier with an additional transistor stage, giving an input impedance of 0.5 megohms and full output for a 40-millivolt input signal. This represents a drift-free power gain of 2×10^9, a value almost impossible with all-magnetic amplifiers. The size (2 15/16 x 1 25/32 x 4$\frac{3}{4}$ in.) and weight (23 oz) are consistently less than what can be achieved by vacuum-tube techniques.

Replacing the transistor in the amplifier of Figure 4 with a vacuum tube gives the amplifier shown in



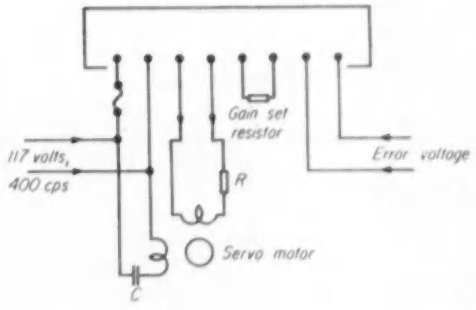


FIG. 4. Photograph and schematic of low-power transistor-magnetic amplifier.

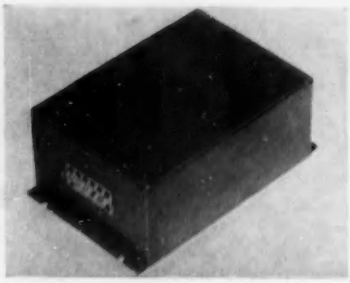


FIG. 5. High-gain transistor-magnetic amplifier; similar to Figure 4 except that it has two transistor stages.



FIG. 6. Vacuum-tube-magnetic amplifier; similar to Figure 4 except that tube replaces transistor.

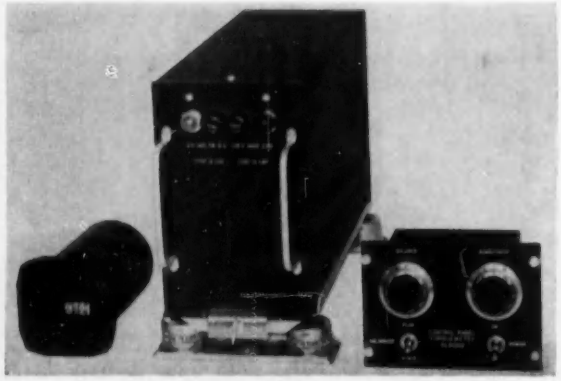


FIG. 7. Vacuum-tube-magnetic strain-gage indicator.

Figure 6. The premium-grade tube is operated at conservative dissipation and element voltages. No power supply is required, for the element voltages are supplied from the magnetic circuits. This amplifier has all the features of the one shown in Figure 4, and in addition boasts higher gain, principally because of the greater stage amplification possible with the vacuum tube. The size is $2\frac{3}{4}$ x $2\frac{7}{8}$ x 5 in. and the weight is 24 oz.

The strain-gage indicator shown in Figure 7 also uses a vacuum-tube-magnetic amplifier. This application is interesting, since the strain-gage bridge is dc-excited, and the amplifier must develop full output for 200 microvolts of dc input. A mechanical chopper modulates the dc error voltage. This is followed by a two-stage tube signal amplifier that drives the magnetic output stage. Only two premium tubes are used, with the B + limited to 20 milliamps at 150 volts dc. The null stability and gain of this unit cannot be achieved with an all-magnetic amplifier, while the size, weight, power consumption, and reliability cannot be matched by an all-tube equivalent.

HIGH-POWER SERVO AMPLIFIERS

For loads greater than those in the instrument class, larger motors and actuators must be used. These could be high-powered versions of the two-phase instrument motor, shunt or series dc motors, clutches, mechanical torque amplifiers, and hydraulic motors. Two examples of hybrid amplifiers are given here, one to drive a high-power 60-cps two-phase servo motor, the other designed for a 30-watt dc motor. Figure 8 shows a 60-cps vacuum-tube-magnetic amplifier driving a 50-watt two-phase motor from a 117-volt, 60-cps line. The system includes a synchro data system and tachometric stabilization. The amplifier weighs 12 lb, and no power source other than 117 volts is necessary.

The unique feature of this amplifier is its high gain and input impedance: a saturation input of 100 millivolts rms at an impedance level of 1 megohm. This allows the synchro and tachometer signals to be mixed with summing resistors, the various scale factors being set by adjusting the resistors.

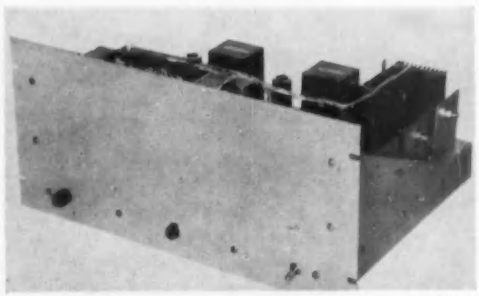


FIG. 8. High-power, vacuum-tube-magnetic amplifier for two-phase servo motor.

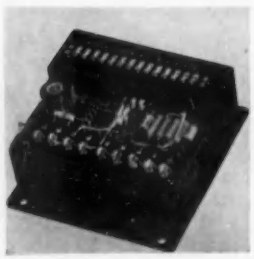


FIG. 9. High-power, transistor-magnetic amplifier for dc servo motor.

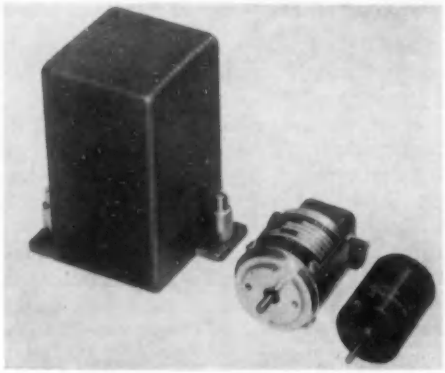


FIG. 10. Transistor-magnetic velocity-servo amplifier with permanent-magnet dc motor and tachometer.

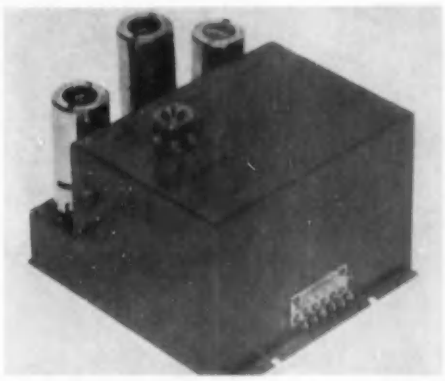


FIG. 11. Transistor-magnetic velocity-servo amplifier for two-phase servo motor.

Only two premium tubes are used, and the element voltages are derived from a low-current selenium rectifier power supply built into the amplifier. The zero is stable, and the amplifier can operate over a wide temperature range.

The amplifier shown in Figure 9 drives a 30-watt dc series-wound motor. The circuitry is transistor-magnetic. Since silicon transistors and power rectifiers are used, operating temperatures of 75 C can be tolerated with no change in gain or zero. There are two transistors in the circuit, one in the amplifier proper and the other in the switching circuit required by the fine- and coarse-speed synchro system. Tachometric stabilization is used.

The interesting features of this amplifier are its size, weight, and efficiency. Overall dimensions are only 3¼ x 7 x 7½ in.; weight is 3½ lb. The efficiency is high, with standby line current approximately one third the current under maximum output conditions. The amplifier responds well, with a time delay of only one-half cycle of line frequency. Cascading additional transistors for high gain does not increase this time constant. The hybrid circuit is versatile and the same type amplifier can be used for dc motors in the integral horsepower class.

VELOCITY SERVOS

Although in most cases a positional amplifier can be used in velocity servos, special amplifier designs often can take advantage of possible simplifications. Thus, if only one direction of rotation is required, the loop need not be reversible; also, velocity servos, more easily stabilized than positional servos, result in amplifiers specifically engineered for speed-control applications.

The amplifier shown in Figure 10 is particularly interesting because it has no vacuum-tube or magnetic counterpart. It is essentially a high-gain, single-ended, dc amplifier with transistor-magnetic circuitry. It drives a miniature permanent-magnet motor from a dc command voltage and a dc tachometer. It is unique because it is a single-ended circuit structure that has little drift, thus allowing a nonreversible velocity servo with good stability and accuracy. The low-drift feature results from the hybrid circuit; it would be very difficult to duplicate its performance with cascaded single-ended vacuum-tube or magnetic stages. As is usual in these amplifiers, magnetics in the output stage generate the 10 watts of dc power for the permanent-magnet motor, and a single transistor serves as a preamplifier. The error signal is amplified as a dc signal, and dc to ac modulation is necessary. The size is 3¼ x 2¼ x 3 27/32 in. and weight is 23 oz. Operation is directly from the 117-volt, 400-cps line.

A more elaborate amplifier is shown in Figure 11. It drives a two-phase, 400-cps servo motor (BuOrd MK 7 Mod 0) in a reversible velocity loop from a dc signal. In this application, output accuracy is paramount, and to avoid all drift errors the dc error signal is modulated with a synchronous chopper.

The output stage is again magnetic with reversible ac output for the two-phase motor. A transistor serves as an ac amplifier, driving the magnetic stage. The two tubes shown serve as voltage regulators for establishing a stabilized dc voltage across the command potentiometer. The circuit package also contains the dc power supply necessary for this channel. Size is 2⅞ x 4 x 4⅛ in. and weight is 29 oz.

Hybrid amplifiers can also be used to drive high-power velocity servos. The dc motor is a favorite actuator because of its higher efficiency and smaller size when compared to a two-phase servo motor. In a typical design for 50 watts of shaft output power, a full-wave, nonreversible magnetic output stage drives the motor, and a two-tube preamplifier raises the signal level sufficiently to drive the magnetics. This circuit has been used with both ac and dc data. In the latter case, a synchronous vibrator modulates the dc error voltage.

Often complex systems require sensing circuits for

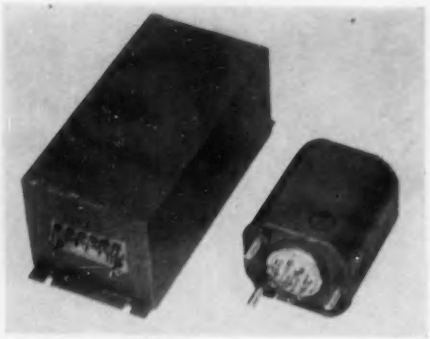


Fig. 12. Transistor-magnetic, 400-cps relay amplifier and relay.

relay operation where the relay must be energized when certain threshold levels are exceeded. Hybrid circuits can be used in this application, since they offer a reliable, sealed package with no power supply required other than the ac line. A single-ended magnetic amplifier can easily supply the few watts of dc power required to drive a relay, while a transistor provides the additional amplification.

RELAY AMPLIFIERS

Figure 12 shows a typical relay amplifier. It drives a sealed, four-pole, double-throw relay with a coil rated at 30 milliamps dc and 400 ohms. The amplifier uses transistor-magnetic circuits, operates reliably at temperatures up to 75 C, and closes the relay with 160 millivolts rms into an amplifier input impedance of 50,000 ohms. The only power required is 117 volts, 400 cps. Size is 1 21/32 x 2 x 4⅜ in. and weight is 18 oz. Like many of the others shown, the circuit is embedded in plastic for maximum environmental protection and reliability.

These relay amplifiers can be made very sensitive by cascading transistor stages. Stability and speed of response are not affected, for the additional stages function as linear ac amplifiers. The theoretical gain limit is set by the noise characteristics of the input transistor.

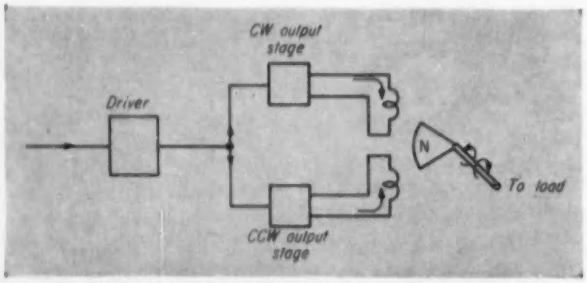


FIG. 13. Schematic of torque motor and amplifier.

TORQUE-MOTOR AND CLUTCH AMPLIFIERS

Some electromechanical actuators use a differential magnetic field to develop a mechanical force. Two current-carrying coils are mounted opposed, so that the net magnetic effect is proportional to the difference current. Thus the reversible eddy-current or hysteresis clutch generates an output torque substantially independent of velocity, and proportional to the difference between the currents in the two drive coils. In the dc torque motor, two current-carrying coils set up a net magnetic field that interacts with that of the permanent magnet rotor to generate a proportional torque over a limited angle. All these actuators are driven by the same type of circuit—single-ended input and two-channel four-wire output, Figure 13.

Again, hybrid amplifiers are well suited to this application. The four-wire dc output is generated by a magnetic stage, and the necessary gain established by a vacuum tube or transistor. Figure 14 shows a vacuum-tube-magnetic amplifier used for driving a dc torque motor. Maximum motor output occurs with one coil cut off and the other carrying 1 amp into 35 ohms. The saturation input is 2.5 volts rms into 0.5 megohms, giving a power gain of approximately 3×10^6. Half-wave magnetic circuits are used for the output stage and the premium tube preamplifier works at low plate dissipation. The amplifier has a stable zero and quiescent level, and the speed of response is substantially that set by the motor-coil time constant. Since this unit is used in airborne applications, it is packaged in a compact, plug-in assembly. Overall size is 3¾ x 4¼ x 7¾ in. and it weighs 2¾ lbs.

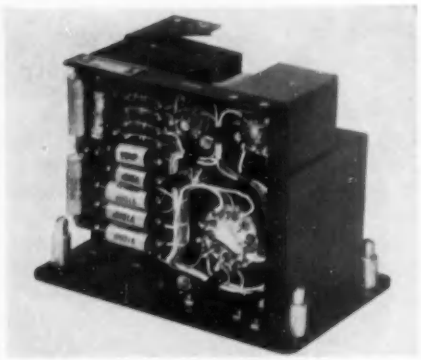


FIG. 14. Vacuum-tube-magnetic torque-motor amplifier.

Acknowledgment: The author wishes to thank Mr. H. G. Eicher for his help in this program.

Be Sure to Consider

HUMAN DYNAMICS

The human operator can inject many vagaries into the control loop. Hence the factors that influence his dynamic response should be considered when the system is designed. In October 1954, this magazine carried an article by Joel Greene, "Man as a Servo Component", which described the effects of position, velocity, and acceleration control signals produced by manual movement of a control lever in a following or tracking situation. In this article the authors consider the other facets of the same situation: the force and displacement characteristics of a control lever that best fit average responses.

NORMAN AVRECH, The Ramo-Wooldridge Corp., and JOHN LYMAN, UCLA

Human operators are often called upon to act as error-correcting mechanisms. In many of these instances the operator's performance cannot be conveniently compacted into transfer functions. Such factors as incentive, fatigue, effective state, and practice vary widely with a given individual and among various individuals, and about the only general statement that covers all of these nonlinearities is that, by and large, humans adapt to a particular task with the most suitable "transfer function" in their repertory of behavior.

An operator can visually ignore his movements as he actuates a control lever or wheel but he will nevertheless receive direct information about these movements from kinesthetic sensory nerves. Located in muscles and near joints, these nerves send their most accurate signals during dynamic conditions. That is, if a muscle is tensed or a position is held for a long period, the associated kinesthetic nerves are not likely to transmit very accurate information on the relative positions of the static members. If the motions are too small, nerve excitation may be limited; if they are too large, the inertia of the body members will retard response time and may introduce highly nonlinear signals. Hence, the portions of the body called on to furnish control forces largely determine the ideal control lever force-displacement relationship. The rate at which the tracked variable changes influences not only the required frequency response of the operator, but also the design parameters of the optimum control system, especially the gain. Some manual control systems have two levels of gain, a simple example being the fine and coarse tuning adjustments of many radio receivers.

Experimental Variables

This article is based on experiments involving human operators who visually discerned error quantities on a cathode-ray oscilloscope and then attempted to reduce the error quantities to zero by either applying a force or a displacement to a control handle. In practice, few systems use extremes of either pure force (isometric) or displacement (isotonic) input. Most control handles require some combination of both. But since either type can be realized in practice through the use of strain gages or potentiometers, knowledge of the relative advantages of either of these control functions is important for the system designer.

Another basic design parameter associated with either type of control actuator is its gain. In the

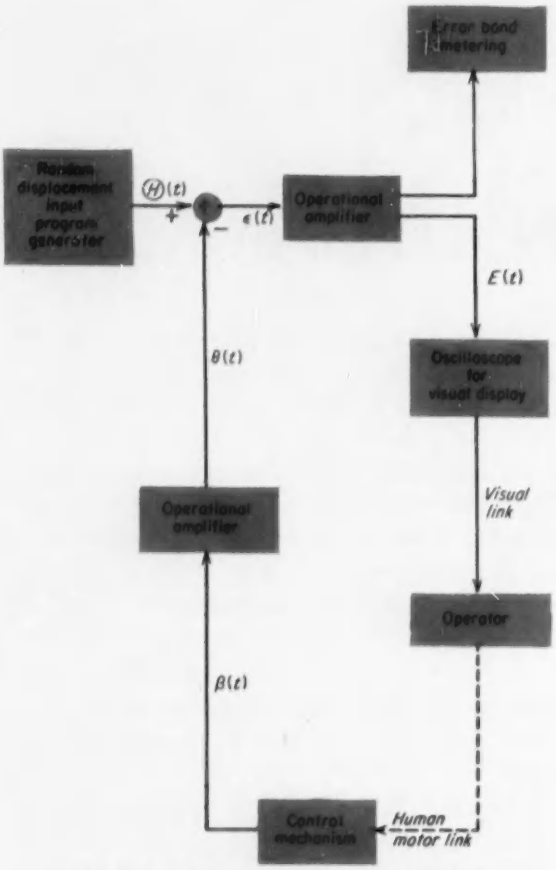


FIG. 1. Block diagram of experimental setup. Within the human operator is a neural loop, primarily a regulator (type 0) positional servo, but with velocity and acceleration components, too. Here frequency-modulated nerve impulses provide the brain with information on limb dynamics and position.

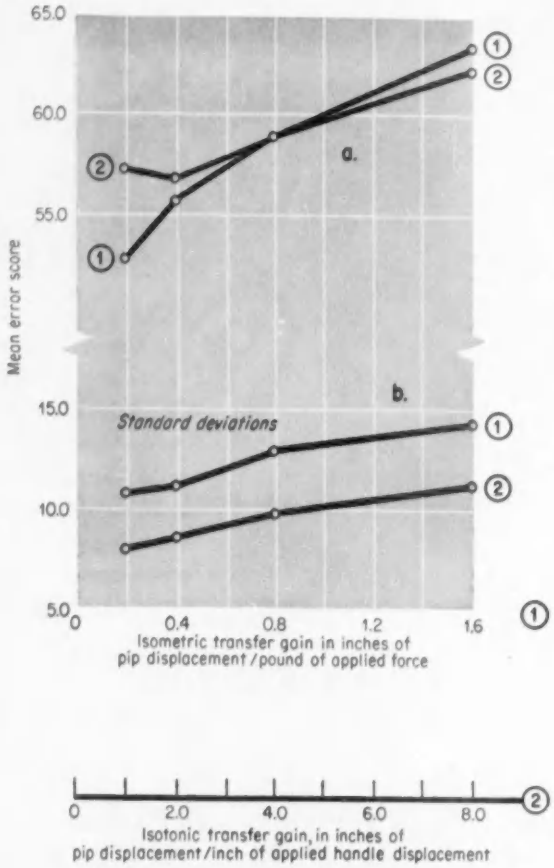


FIG. 2. Gain for either force or displacement (isometric or isotonic) plotted as a function of mean error. Note that the standard deviations of the most accurate mode (force at low gain) are greater for displacement-signal-activated control systems at any gain level.

experiments described here, this gain is that of the amplifier, relating a pip displacement to a control-lever displacement or force. C. B. Gibbs demonstrated that each type of control (force or displacement) has some optimum gain for a given error signal frequency, and that the force type of actuator yields smaller average errors.

In many actual systems the effects of an input to the control actuator is proportional to the duration as well as the magnitude of the input. These systems are called "rate aided", and have "rate aiding" time constants. An example of such a condition is steering a car. Either a small or maximum rotation of the steering wheel can cause the auto to turn a full circle, but if the car has a constant speed, the small rotation will require a large turning radius, and consequently more time for the full circle to be completed. The choice of the time constant (speed, in the case of the car) is roughly of the same importance as the gain (steering wheel ratio) in the design of a human-controller system.

Figure 1 shows the experimental setup used to explore the influence of force and displacement controls and gain or rate-aided time constant on tracking accuracy. This research was carried out at the Biotechnology Laboratory of the Engineering Dept. of UCLA.

The Setup and Results

Sixteen male subjects from 23 to 30 years old observed a pip on a cathode-ray tube moving in horizontal steps of four right-hand or left-hand magnitudes taken in random sequence. The deflection voltage was terminated after each step so that the pip returned to its central position after each deflection before the next offset. Each test run lasted for 1 min, with the steps appearing intermittently at times ranging from 0.41 to 1.50 sec. The

subjects were instructed to return the pip back to its central position after any deviation as rapidly and as accurately as possible by means of a bicycle handle.

Three error bands were established in computing a weighted "time off target" score as an error criterion measure. A resumé of the experiment's results appears in Figures 2 and 3. Figure 2A suggests that superior performance is obtained with both control systems at low values of transfer gain (that is, when either a large force or displacement produces a given pip motion). This experiment did not determine the lower limit of gain for the force-deflection system, but indicated an optimum ratio of about 2 in. of pip movement to 1 in. of control movement for the isotonic system. An important factor to keep in mind about the force-deflection system's results is the high rate at which fatigue will increase with low-gain force systems. Therefore, the duration of the control situation must be considered in establishing the optimum force gain.

The results of this experiment correlate with studies of force-discrimination made by various psychologists. That is, curves of force-discrimination (size of discrimination increments versus applied force) indicate high sensitivity to force changes in the range of the low-gain forces used in this experiment. The evident superiority of force control at low-gain levels may be, in part, associated with the "self-centering" characteristic of this type of control. One might also say that the nervous system is more sensitive to muscle tension than to limb motion. The self-centering characteristic of the isometric control was absent in the isotonic control, and as both became more sensitive at high-gain levels, the advantage of the force control tended to decrease, possibly because of loss of self-centering. Finally, it reached the point where the control became excessively sensitive to minor force variations, such as the natural tremor of the operator's hand.

Variability

For practical applications, the relative variability of performance with the two types of control is an important consideration. Even though the average score obtained in one system may be superior, score variation among this system's test subjects might be greater. The standard deviations of the various transfer gains and time constants are plotted in Figures 2B and 3B. While the mean scores in Figure 3A indicate that the isometric (force) control is clearly superior for all time-constant levels with rate-aiding systems, the standard deviations (rms of the deviations) were less for the isotonic (displacement) system, except at one rate level. This implies that for rate-aided systems, and possibly for some simple positioning systems, isometric (force) controls offer higher average accuracy, but isotonic (displacement) controls offer greater uniformity of performance. This means that the scores of the isotonic system are clustered closer to their mean value, and that a "position boost" (a corrective displacement which accounts for operator time lag during accelerating target conditions) will produce better scores with the isotonic system than with the isometric, despite the latter's generally superior average score without position boost. Studies now in progress will determine what generalizations can be made concerning the optimum combination of force- and displacement-actuation modes. They will probably extrapolate the results indicated here. At the least, this study should provide the system designer with some idea of the magnitude of operator-performance improvement obtainable by attention to the human transfer function.

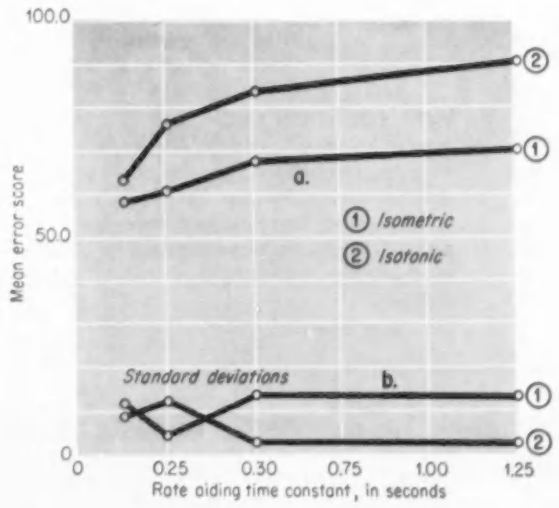
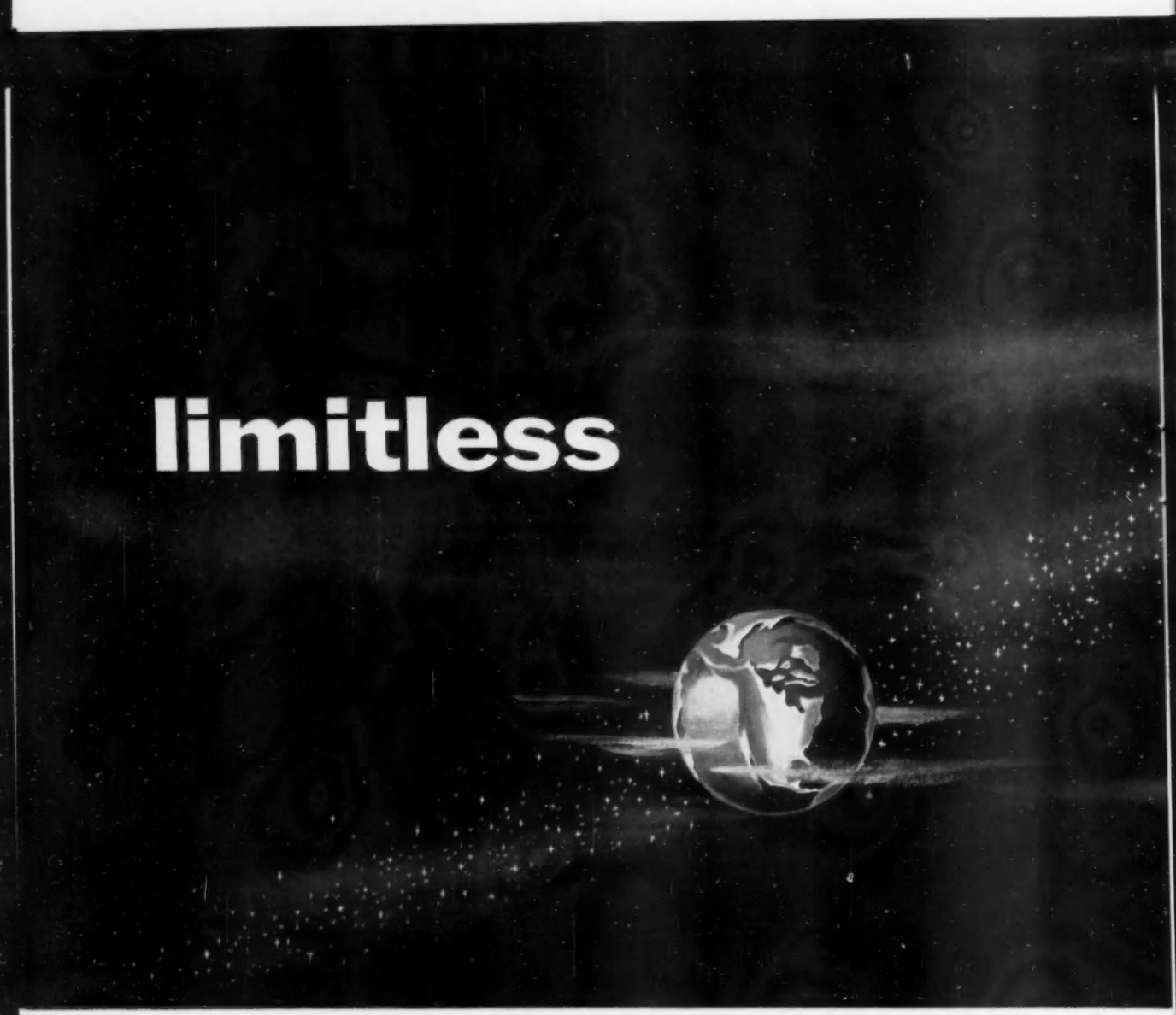


FIG. 3. Mean errors in rate-aided control situations are consistently less with isometric (force) control levers, but their standard deviations indicate greater variability of performance.



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Programming Scientific Calculators

THE GIST: Programming a problem on a calculator consists of two major steps: putting the problem into a form that the computer can solve; and translating this form into a language that the computer can understand. The scientist or mathematician gives the problem to the programmer completely described in mathematical form. But this form is generally not one that the computer can work in. Hence the programmer must numerically analyze the problem, transforming it into still another mathematical formulation applicable to a computer's repertoire of basic arithmetic operations. Here the problem can be represented by a flow diagram, which then is translated into the computer's own language by a process called coding. This translation is done by hand, although sometimes automatic coding or computer-aided programming assists the coder. These procedures are described in the following pages, and illustrated by a problem actually solved on the NORC.

JOSEPH H. WEGSTEIN and SAMUEL N. ALEXANDER, National Bureau of Standards

Before a problem or "situation" is programmed for calculator solution, the situation must be described in terms of mathematical formulas or equations. This means erecting a mathematical model of the situation. In the field of physics, very elaborate mathematical models or equations exist for describing such physical phenomena as the forces within an atom. Sometimes two radically different mathematical models can be used to describe the same phenomenon. For example, the flow of neutrons in a nuclear reactor can be likened to the flow of water, and as such can be described mathematically by partial differential equations solvable with a computer. On the other hand, neutrons can also be regarded as aimless wanderers, and here, too, their paths can be traced, this time by the computer. Tracing millions of these neutron paths might give information similar to that obtained by solving the partial differential equations. In either case, some of the performance characteristics of a given nuclear reactor can be anticipated before it is built.

In the military field, the flight of projectiles can be described in terms of differential equations. Such things as the angle of elevation of a gun, initial projectile velocity, wind velocity, and direction with respect to the earth's rotation are fed into a computer as parameters along with the equations. The computer then solves these equations and prints out answers that include such useful information as how high the projectile will go and where it will explode. The basic idea is to mathematically imitate a physical situation and, by solving the equations, anticipate the results without actually seeing or doing the experiment.

The need for projectile data gave the initial impetus to development of large-scale computers. However, as these computers began to appear, it became possible to investigate some physical situations for the first time, particularly where large quantities of data were involved[1]. Weather prediction is one; another is production scheduling in factories, setting up mathematical models of a factory on a computer. A large catering firm in England uses its computer to determine baking and delivery schedules based on incoming orders; in its spare time the computer handles the payroll for about 33,000 people. New computer applications require problem formulation by an applied mathematician or physicist who is willing to depart from traditional considerations.

Figure 1 shows how an actual problem looks after it has been formulated. This is a facsimile of a problem submitted by Drs. R. Jastrow and J. Ehrman of the Nucleonics Div., Naval Research Laboratory, to the Computation Laboratory, National Bureau of Standards, for programming and solution on the Naval Ordnance Research Calculator (NORC) at the Naval Proving Ground, Dahlgren, Md.

PROGRAM FOR COMPUTATION OF PARTICLE TRAJECTORIES IN THE FIELD OF THE EARTH

I. EQUATIONS OF MOTION

We wish to study the trajectories of charged particles, primarily protons, in the field of the earth, represented by a magnetic dipole.

We use a cartesian coordinate system (x, y, z) with the z-axis directed opposite to the axis of the dipole. The equations of motion for the particles are, in Störmer units,

$$\ddot{x} = -(x^2+y^2+z^2)^{-5/2}\ [(2z^2 - x^2 - y^2)\dot{y} - 3yz\dot{z}] \quad (1a)$$

$$\ddot{y} = -(x^2+y^2+z^2)^{-5/2}\ [(x^2 + y^2 - 2z^2)\dot{x} + 3xz\dot{z}] \quad (1b)$$

$$\ddot{z} = +3z\,[h(x^2+y^2+z^2)^{-5/2} + (x^2+y^2)(x^2+y^2+z^2)^{-4}] \quad (1c)$$

where h is a constant for each trajectory and is computed from the initial conditions specifying that trajectory, according to the formula in Section II. An additional relation is provided by the equation

$$\dot{x}^2 + \dot{y}^2 + \dot{z}^2 = 1 \quad (2a)$$

Equation 2a may be used as a check on the integration of Equations 1a, 1b, and 1c.

II. INITIAL CONDITIONS

The initial values of x, y, and z are expressed in terms of parameters a, b, and α according to the relations

$$x = 6\sin\alpha - b\cos\alpha \qquad \dot{x} = -\sin\alpha$$
$$y = -a \qquad \dot{y} = 0$$
$$z = 6\cos\alpha + b\sin\alpha \qquad \dot{z} = -\cos\alpha$$

The constant h, which appears in Equation 1c, is computed from the initial values for each trajectory by the formula

$$h = (x\dot{y} - y\dot{x}) - (x^2+y^2)(x^2+y^2+z^2)^{-3/2}$$

The trajectories are to be computed for all combinations of the following values of a, b, and α:

a: $\pm 1.2, \pm 0.5, \pm 0.2, 0$
b: $\pm 1.2, \pm 0.5, \pm 0.2, 0$
α: 55 deg, 72.5 deg, 90 deg

The total number of trajectories is thus $7 \times 7 \times 3 = 147$.

III. CRITERION FOR HALTING THE INTEGRATION

The stopping criterion, as well as the choice of the integration interval, depend on the curvature C of the path, defined by

$$C^2 = \ddot{x}^2 + \ddot{y}^2 + \ddot{z}^2 \quad (3a)$$

FIG. 1.
From scientist
to programmer.

The First Step of Programming

NUMERICAL ANALYSIS

Once a mathematical statement has been obtained, the problem must undergo a further step, which may be called analysis. As the physicist or applied mathematician writes them, formulas and equations are often generalized, but are not necessarily in a form that can be handled numerically. For example, x_s may be required, where x_s is the root of the equation

$$ax^2 + bx + c = 0 \quad (1)$$

and several different values for a, b, and c are to be tried. This is quite specific, but before the equation can be fed into a computer, an exact method for getting x_s must be specified that depends solely on repetitively performing the common arithmetic operations of addition, subtraction, multiplication, and division. For example, the formula

$$x_0 = \frac{-b + \sqrt{b^2 - 4ac}}{2a} \quad (2)$$

can be used instead of Equation 1 once it has been established that this formula represents the desired root.

To give another example, the problem might specify that a value of y be used that corresponds to a particular value of t, where the relationship between y and t is given by the equation

$$a\frac{d^2y}{dt^2} + b\frac{dy}{dt} + cy = e \quad (3)$$

and certain specified boundary conditions. An analysis will specify exactly how to numerically get the value of y corresponding to the given value of t.

This type of analysis has been somewhat simplified by a growing body of available numerical techniques for handling the more standard mathematical expressions.

In analyzing the problem of Figure 1, the differential equations had to be replaced by difference equations so that they could be numerically integrated by the computer. Thus new variables were introduced as follows:

$$u_1 = \frac{dx}{ds} = \dot{x}$$

$$u_2 = \frac{dy}{ds} = \dot{y}$$

$$u_3 = \frac{dz}{ds} = \dot{z}$$

$$u_4 = x$$
$$u_5 = y$$
$$u_6 = z$$

Then the Runge-Kutta method[2] for integrating simultaneous second-order equations could be applied and the formulas appear as follows:

Letting $\frac{du_i}{ds} = f_i(u_1, u_2, \ldots, u_6)$ define f_i,

then:
$$k_i = f_i(u_1, u_2, \ldots, u_6)\,\Delta s$$

$$l_i = f_i\left(u_1 + \frac{k_1}{2}, u_2 + \frac{k_2}{2}, \ldots, u_6 + \frac{k_6}{2}\right)\Delta s$$

$$m_i = f_i\left(u_1 + \frac{l_1}{2}, u_2 + \frac{l_2}{2}, \ldots, u_6 + \frac{l_6}{2}\right)\Delta s$$

$$n_i = f_i(u_1 + m_1, u_2 + m_2, \ldots, u_6 + m_6)\,\Delta s$$

$$\Delta u_i = \frac{1}{6}(k_i + 2l_i + 2m_i + n_i)$$

The same subroutine can be used to evaluate f_i in each formula, and successive applications of this set of formulas give the increase in each variable u_i for each increase in time Δs. For example, a plot of successive values of u_4 equals x against time, s, gives the x-coordinate of the particle as it travels through space. Curves for the values of y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$ are obtained in a similar manner.

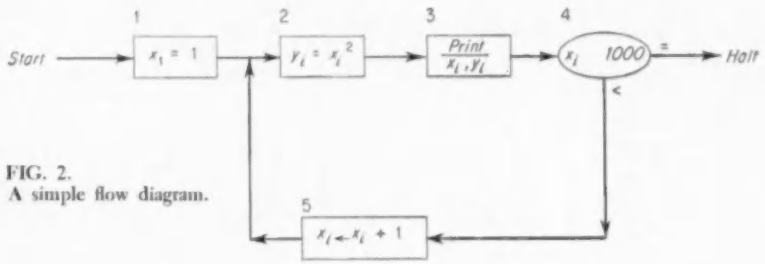


FIG. 2.
A simple flow diagram.

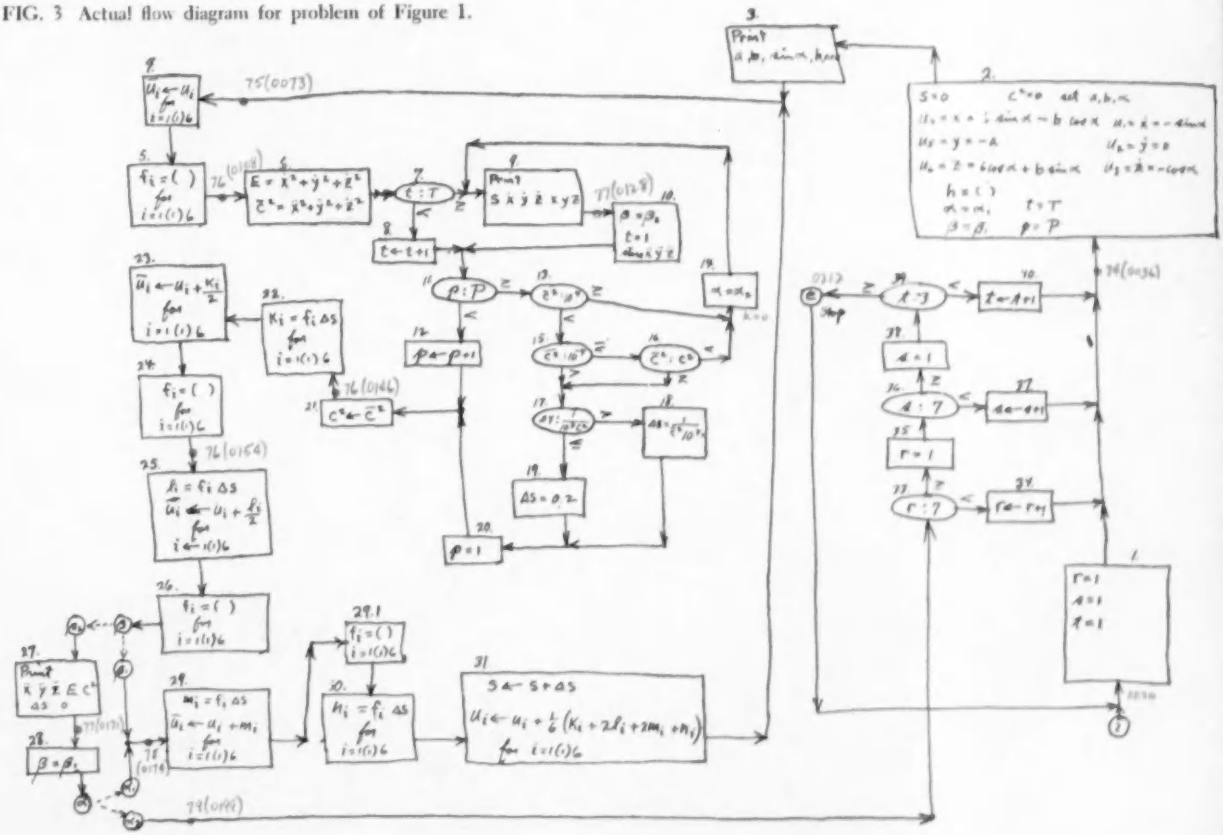
By the time the analysis of a large problem is completed the equations and related notes are extensive and cumbersome. And it is at this point that the programmer must be able to visualize the whole problem, paying particular attention to the manner in which all the parts must fit together. A very useful technique, called flow diagramming, has been prescribed for this purpose, by Goldstein and von Neumann[8]. A kind of block diagram is drawn, depicting each step to be followed in the calculation.

Suppose that a computer is to prepare a table of integers from 1 to 1,000 and their squares. Using tablemaker's notation, this can be restated mathematically: prepare a table of x_i and y_i where y_i equals x_i^2 and x_i equals 1 (1) 1,000 (x goes from 1 to 1,000 in steps of 1). Notice that these few words specify a rather lengthy calculation. Figure 2 restates the same concept in flow-diagram form.

Flow diagrams differ in detail, but they are sufficiently similar to be readily understood by programmers of different schools. Box 1 sets the first value, x_i equals 1. Box 2 then computes y_i equals x_i^2 equals 1. Box 3 is separated from Box 2, because Box 3 represents a special type of operation. Thus, formula instructions are separated from input or output instructions. An oval box is almost universally used to indicate a comparison, and Box 4 means "Compare the value of x_i with 1,000." This kind of box has at least two exits. If x_i is less than 1,000, the computation proceeds to Box 5 via the "<" exit. Here the value of x_i is replaced by its previous value plus 1. Thus the new x_i equals 2. The computation then proceeds around the loop of Boxes 2, 3, 4, 5; 2, 3, 4, 5; etc., until x_i equals 1,000. For this condition, the process leaves Box 4 via the "=" exit, and the computation halts.

With this technique, a flow diagram for an entire problem can be built up, usually on one large sheet of paper. It is a job for a pencil because the diagram may be changed many times during its evolution. The diagram continues to develop in this rough pencil form until the problem is being successfully solved on the computer, because minor logical errors often remain in the diagram until the problem is tried out on the computer. Figure 3

FIG. 3 Actual flow diagram for problem of Figure 1.



is the actual flow diagram used for the problem described in Figure 1.

This problem stated that the parameters a, b, and α are used to compute the initial position and velocity of the particle. Various initial conditions are obtained by using the different values indicated for a, b, and α in the table at the end of Section II in Figure 1. For the computer to run through this table, indices r, s, and t are assigned to the parameters a, b, and α, respectively. These indices run through the values 1, 2, 3, etc., while the computer runs through the table. Thus, when r equals 1, a equals 1.2; when r equals 2, a equals 0.5; etc. These indices do not appear in the computer as actual integers, but they imply that the addresses of certain instructions are being modified. In Figure 3, Box 1 sets the instructions to obtain a equals 1.2, b equals 1.2, and α equals 55 deg. In Box 2, the initial values for the dependent variables are computed. In Box 3 the computer is instructed to identify the trajectory by printing a line on the monitor printer. The computer then enters a loop at Box 4, in which the Runge-Kutta formulas are used to compute a new point in the trajectory. The new point is finally obtained in Box 31. The control immediately returns to Box 4, where computation of the next point begins.

Boxes 7 through 20 are concerned with determining when to terminate the trajectory, what to use as a new time increment, and how often to print the position and velocity data for the particle. To obtain high accuracy, a very small increment of time, Δs, must be used. However, it is not desirable to print the position and velocity data at each of these integration steps. Instead, Boxes 7 and 8 indicate that the computer is to count steps, and after every Tth step (e.g., if T equals 10, after every tenth step) to print the value of the position and velocity coordinates.

When the trajectory becomes sufficiently linear, Box 14 sets the remote connector α equals α_2. This prepares to terminate the trajectory, and later, after Box 28, control passes to α_2. With α_2 in control, the process proceeds to Box 33 and on to Box 2, where new initial conditions are determined and the calculator begins computing a new trajectory.

Flow diagrams also permit the programmer to verify logically the sequence of everything to be calculated. It is interesting to note that at this point the entire problem can sometimes be turned over to an operator with a hand calculator.

The Third Step of Programming | CODING

FIG. 4. Part of the code.

EXPLANATION		LOCATION	P	Q	R	S	T
1017 $f_5 = \overline{U_2}$ f_{11}		0105	00	60	1001	1017	0106
1018 $f_6 = U_3$		0106	00	60	1002	1018	1064
↪ 0108	(1064)	0107	00	60	0000	0000	0108
	76	0108	00	76	0000	0000	0109
1990 $\dot{x}^2$		0109	50	24	1016	1016	1990
1991 $\dot{y}^2$		0110	50	24	1017	1017	1991
1992 $\dot{z}^2$		0111	50	24	1018	1018	1992
1990 $\dot{x}^2+\dot{y}^2$		0112	50	20	1990	1991	1990
1043 $E=\dot{x}^2+\dot{y}^2+\dot{z}^2$	6.	0113	50	20	1990	1992	1043
1990 $\dot{x}^2$		0114	50	24	1013	1013	1990
1991 $\dot{y}^2$		0115	50	24	1014	1014	1991
1992 $\dot{z}^2$		0116	50	24	1015	1015	1992
1990 $\dot{x}^2+\dot{y}^2$		0117	50	20	1990	1991	1990
1044 $\overline{c}^2=\dot{x}^2+\dot{y}^2+\dot{z}^2$		0118	50	20	1990	1992	1044
$T-t:0$	7.	0119	00	70	0913	1057	0134
1057 $t \leftarrow t+1$	8.	0120	00	40	0925	1057	1057
$P-p:0$	18.	0121	00	70	0914	1058	0131
1058 $p \leftarrow p+1$	12.	0122	00	40	1058	0925	1058
1046 $c^2=\overline{c}^2$	21.	0123	00	60	1044	1046	0146
$M_4=0$		0124	00	57	0000	0000	0000
load mq1 — 0007		0125	00	80	5006	4001	0126
$M_4 \leftarrow M_4+1$ $M_4:7$	9.	0126	00	58	0001	0007	0125
Print S, $\dot{x}$, $\dot{y}$, $\dot{z}$, xyz		0127	00	81	1097	0000	0128
	77	0128	00	77	0000	0000	0129
1060 $\beta = \beta_2$	10.	0129	00	60	0164	1060	0130

To perform this coding, the programmer must have a detailed knowledge of the operation code for the particular computer to be used. The next step is to rewrite the problem from the flow diagram into a language understood by this computer.

The central feature of a modern high-speed scientific computer is its memory, in which information is stored in the form of words. Usually these words are of fixed length, and the location of each word is designated by a number called its address. Thus in the UNIVAC, with a 1,000-word memory, the location of these 1,000 words is addressable from 0 to 999. Each word can be used either as a number (parameter of an equation), or as an instruction that tells the computer what to do. In the UNIVAC a word used as a number consists of a sign and eleven decimal digits. How a word instructs a computer varies from one computer to another, but the basic principle is always the same.

In the addition operation, for example, the instruction tells the computer: "Take a number from one address, add it to the number from a second address, and store the sum at a third address." Some computers require two or three words for this operation, while others, like the NORC or SEAC, need only one word. When executing a program, the computer transfers an instruction word from its memory to a control register where the word is interpreted. The computer acts according to the instructions encoded in this word. As soon as the

meaning of this word is exhausted, the computer transfers another word from memory to control register and proceeds to follow this next set of instructions. Computers execute these instructions at high rates of speed.

In coding, a programmer traces through a flow diagram, such as shown in Figure 3, writing instructions in the form of computer words so that the computer will perform the indicated calculations. Figure 4 is a portion of the code for the NORC for the problem indicated in Figure 1. Note that the word to be stored at location 0112 is an addition instruction. The 20 in column Q means add the number at address 1990 (which is $\dot{x}^2$) to the number at address 1991 (which is $\dot{y}^2$), and store the result ($\dot{x}^2$ plus $\dot{y}^2$) at address 1990. (The NORC memory consists of 2,000 words in addresses 1 to 2000.) The words in locations 0109 through 0118 are actually the code corresponding to Box 6 in Figure 3. Figure 4 also includes the code corresponding to Boxes 7, 8, 11, 12, 21, 9, and the beginning of Box 10. Note that the programmer made two mistakes on this page of code. Mistakes are inevitable, and are one reason for a delay in getting the code to properly control the computer. The complete code for this problem required about 350 words or lines of code. Two days were required to write this code, but about a week elapsed before all constant and variable storage locations were reasoned out and proper constants were chosen.

When the code is completed, it and any necessary constants or parameters are placed on an input medium for the computer, such as punched cards, teletype tape, or magnetic tape. The problem is then ready to feed into the computer for checking.

CODE CHECKING

Codes are often several hundred words in length, and every character in them must be logically correct if the computer is to yield the correct results. Consequently, the most skillful programmer seldom succeeds in arriving at a correct computer code before it is tried out on the computer. Several short "code checking" sessions on the machine are usually necessary, during which an operator tries to make the computer run through the code. The coder, usually present at these sessions, retires to the quietude of his desk after each one to study the flow diagram and code in light of the behavior symptoms of the computer. When an error is found, it is corrected and another code-checking session is scheduled. After several such sessions, a working code is attained. Then computer solution time can be scheduled.

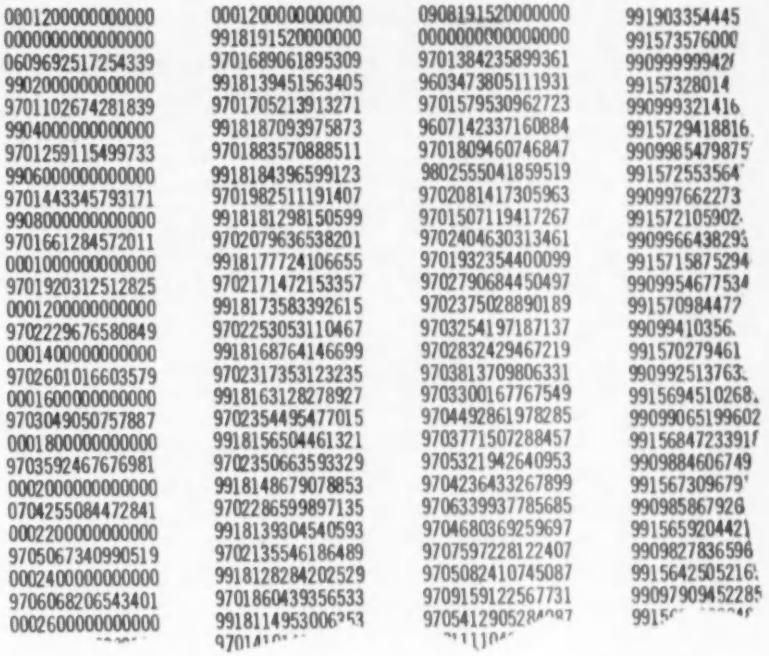


FIG. 5. A portion of the printout.

To facilitate checking the problem illustrated here, several "breakpoints" were placed on the flow diagram in Figure 3. For example, "75(0073)" occurs just ahead of Box 4, and "76(0107)" occurs between Boxes 5 and 6. These are merely points at which the computer stops and which can be identified by the operator. Once the code works correctly, these points are removed. During the first computer code-checking session on the trajectory problem, the NORC successfully reached the following breakpoints: 74,(0036) just ahead of Box 2, 75(0073) just ahead of Box 4, and 76(0107) just ahead of Box 6. However, it failed to arrive at breakpoint 76(0146) which follows Box 21. After printing out the values of certain parameters, the programmer left the computer and re-examined the code from Box 6 through Box 21. He then discovered the error in line 119, Figure 4, and after correcting it, was ready to try again. Five code-checking sessions on the NORC of 5 to 15 min each were required before the code was ready for a production run. These sessions were spread over a week.

COMPUTER OUTPUT

For many scientific problems, the form in which the results are presented may not cause any difficulty, since only a few quantities are of interest to the scientist who proposed the problem. However, there are many situations that are of an exploratory character, leading to large volumes of data that must be presented for inspection and analysis. From this inspection, the scientist who presented the problem can gage whether or not his initial estimate of the number of parameters and the range over which they are to be explored will actually reveal the results he is seeking.

Figure 5 shows a portion of the printout called for by Print Box 9 and Print Box 27 in Figure 3. About 30 lines are required for each trajectory as specified in Figure 1. Two lines are required to describe each point along the trajectory, including position, velocity, and acceleration coordinates, time elapsed, curvature, energy, and the time interval. These printouts permit an inspection of preliminary results, and often lead to a re-definition of the required end results. However, this bulk of information has been purchased at the price of ease in identifying and interpreting the printed numbers. Figure 5 indicates that a more suitable means of quickly presenting the general character of the solutions would be helpful. There is a current trend toward automatic curve-plotting or direct curve display where intricate and voluminous output must be inspected to devise the future course of computation.

PROGRAMMING PERSONNEL

Programming probably proceeds at its maximum rate when only two individuals are involved: a specialist in the scientific subject matter and a good programmer. The scientist or applied mathematician communicates his mathematical statement of the

problem to a trained programmer. The latter completes the numerical analysis, prepares a flow diagram, writes the code, and then personally checks it out on the computer, converting it to a running code. In some organizations there has been a tendency toward greater specialization: the numerical analyst begins the programming by carrying the problem through the flow diagram stage. Then a coder, working from this plan, prepares a code and checks it out on the computer. In this way a running code is attained, and necessary modifications entered on the flow diagram.

If it is necessary in the course of a problem to investigate a wide range of parameters, it may be efficient to subdivide the work further by turning the problem over to an operator who will stay with it during the "production" computation. Naturally, the operator must have explicit instructions from the coder, and ready access to him, in case of trouble.

If the impression has been given that the path from preformulated problem to a working code can be tripped through lightly, then it is time to point out that there are pitfalls along this route. Even for a small problem, as much as a month can elapse from the time the formulated problem is presented until it is actually being solved on the computer. The elements that absorb time until a running code is completed have been briefly described without indicating the time distribution for the several steps. This distribution is highly dependent on the nature of the problem and the skill and experience of the programmer.

In addition, there are delays that can be attributed to equipment malfunctions and the tight operating schedules prevalent for all major installations. The experience of the programmer is nowhere so evident as in the arrangements he makes in his codes for corrections or for minimizing re-runs that result from machine malfunction or operator errors.

It is interesting to note that the work loads for some problems can extend into many hours of computer time, despite the recognized speed of computers. These just happen to be problems of enormous proportions, and without modern computers, other and usually more expensive procedures would have to be used to attain the information being sought, if it could be attained at all.

AUTOMATIC CODING

Many efforts are being made to simplify programming and improve equipment. Until computers can be redesigned in the light of experience, programmers must enlist the aid of the computer itself in programming. Computer-aided programming or automatic coding is basically an effort to get the computer to accept the problem in a language more nearly resembling mathematics than its own code. Indeed, most codes written these days are not true computer codes, but rather are pseudo-codes that the computer itself translates to true computer codes. Various builders and users of computers have developed automatic-coding systems, and have usually made them available to others. For example, General Electric has its CAGE, United Aircraft its SAP, IBM its AP-1, and Remington Rand its Autocompilers.

The actual code for the IBM 704 is a sequence of binary numbers that may be written as octal numbers for convenience. However, these numbers are not easily understood. On the other hand, if the SAP system is used, the code is much easier to write and understand. Consider the code for the formula $y = ax^s + b$.

As an IBM 704 octal code:	As a SAP pseudo code:		
	Loc.	Oper.	Addr.
+056000001451	P1	LDQ	X
+026000001451		FMP	X
+060100001454		STO	T
+056000001454		LDQ	T

In the SAP code the column labeled "Operation" contains letters which suggest the operations they specify, while the column labeled "Address" indicates where the numbers come from and where they are stored. The "Location" column contains entries only at points where control is to reenter the code.

LDQ X means load x into the multiplier-quotient register. FMP X means multiply, in floating point arithmetic, the contents of the multiplier register times x and thus obtain x^s. STO T means store x^s in a temporary location T, and so on through the code. The computer accepts the code in this form and converts it to its own true code before starting to solve the problem.

Coding in this form is relatively easy for an experienced programmer, but it does require considerable knowledge of the computer. Direct acceptance by a computer of problems stated in numerical mathematical form is assured in future advances in computer-aided programming.

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The Computer's Memory

Article No. 6 in this series (CtE, March 1956) described short-time storage elements that are used in computers to hold logical results from one operational step to another. To be discussed now are the long-time storage elements—the computer's memory cells. Mr. Fowler groups these storage devices according to the method used to gain access to their data. He describes the operation of all the more important known storage systems, and compares their principal characteristics.

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One of the most important components of a digital computer is its storage system. The selection of a computer with the wrong storage system will reduce the effectiveness of an entire operation: insufficient storage capacity cramps the operation and often necessitates extra calculations and extra manipulations of data, and a storage system that operates too slowly may cause a severe bottleneck. On the other hand, the special properties of a particular kind of storage system can sometimes be exploited to effect economies elsewhere in the computer. These situations are present in computers currently in operation.

Although storage systems differ in many respects, they are all used to perform the same principal functions. First, they receive and record information which will be needed later on. Second, they preserve that information until it is needed. Third, they deliver that information when it is required.

To perform these functions, a digital storage system must have the following properties:

SIX ATTRIBUTES OF A DIGITAL STORAGE SYSTEM

1. It must contain elementary locations, each of which is capable of storing a digit. In this discussion, these elementary locations will be referred to as memory cells. At present, most memory cells have been constructed to store binary digits, which are called "bits".

2. The memory cells are combined in relatively small groups which will be referred to as "memory boxes". The number of cells in a memory box is usually fixed and uniform. The information stored in a memory box is usually referred to as a "word".

3. The memory boxes are assigned numbers known as addresses. In this way, any word in the storage system can be identified by the address of the memory box in which it is stored. It may be helpful to think of the words stored as being represented by an algebraic symbol consisting of a letter with a subscript, where the subscript is the address.

4. There must be a method of recording information at any desired location in the storage system.

5. There must be a method of reading information from any desired location in the storage system.

6. There must be means of communication between the storage system and the rest of the computer.

There are also properties that distinguish one storage system from another. Among these are capacity, mode of access, access time, and permanence. Other factors, such as bulk and power consumption, are also important.

The capacity of a storage system does not necessarily depend upon the type of components used. It is always possible to add more components of the same kind until the desired capacity is achieved. However, the capacity does influence the selection of the storage system. Some storage devices, economical for low capacities, especially when economic factors other than the cost of the storage system itself are important, cannot compete with systems of very large capacity if the latter are required.

Storage systems are increasing in capacity as the computer art develops. Where computers are used for theoretical calculations, the range of capacities runs from about 50,000 bits to several million bits. In some data-handling systems, extremely large capacities are used. In other data-handling systems, the storage system is extremely small. In this case, the flow of data is planned in cycles so that in each cycle a small quantity of information comes in through the input, is manipulated into the desired form, and then goes out through the output. In control computers, the data also passes through the computer in small batches so that here, too, a small storage system can be used.

To appreciate the importance of having a large storage capacity, consider the number of binary digits required to store a single typewritten page. If elite type were used, there would be twelve characters per horizontal inch and six lines per inch. Thus, a single-spaced page with allowance for margins would contain about 4,500 characters. Assuming that approxi-

mately five binary digits are required for each character, 22,500 bits would be required to store the contents of the page.

Consider also the storage capacity required for mathematical tables. With a sufficiently accurate table of logarithms, the computer could be saved time if the logarithms of factors were added instead of multiplied. To multiply two 30-bit factors and get a result rounded off to 30 bits, the values of about 500 million logarithms would have to be tabulated, with about 32 binary digits for each logarithm. This would require a storage capacity of 16 billion bits. Digital computers will probably do ordinary multiplication and division for a long time to come.

To tabulate 30-bit values of the sine at intervals of 0.01 sec would require a storage capacity of about 10 million bits for that purpose alone. For this reason, when values of the sine are required in a digital computer program, they are usually calculated by a series expansion.

TABLE I COMPARATIVE CHARACTERISTICS

	MODE OF ACCESS			PERMANENCE		
	Cyclic	Parallel	Progressive	Erasable	Nonerasable	Volatile
Magnetic drum Magnetic tape loop	■			■		
Delay line Dual-head magnetic track	■					■
Coincident-current magnetic core Ferroelectric		■		■		
Punched cards (Keysort)		■			■	
Williams tube Diode capacitor		■				■
Magnetic tape Magnetic wire Notched disc Potter random access memory			■	■		
Punched cards (IBM or RemRand) Punched tape Photographic tape			■		■	

MODE OF ACCESS

Another of the storage system properties previously mentioned is the mode of access. It is customary to classify storage systems into two modes of access—parallel and serial. In this article, however, storage systems will be classified into three modes of access: parallel, cyclic, and progressive. In the parallel mode, the reading and writing devices are separate from the memory cells and a switching scheme is used to connect them to the memory cells to which access is desired. In the cyclic storage scheme, the reading and writing devices are again independent of the memory cells, but each memory cell is connected periodically in its turn with the reading and writing devices. In the progressive access systems, the reading and writing devices move physically from the memory box just used to the memory box about to be used. The access time depends upon the proximity of the address called for to the address previously used or to a neutral position.

Most storage systems are not exclusively in any one of these categories. For example, a storage system may be divided into channels, each of which might be a cyclic storage system, but the access to a particular channel might be parallel. In such cases, this article will give most weight to the characteristics of the individual channels.

In some computers, two storage systems are used, one having a short access time and the other a long access time but a large capacity. The access time is related to the mode of access. In a parallel access system the access time is divided into two or three periods, which may overlap. The first period is the time required to couple the reading and writing devices with the particular memory box selected. The second is the time required for reading or writing. This time may include a settling time for the reading and writing devices to recover enough from reference to the storage system to be ready for the next operation. The third period applies only to memory devices having a property known as destructive readout. In these devices, the contents of a memory box is erased when the memory box is read. Therefore, after a read operation, it is necessary to restore the word to its memory box by a writing operation. The time for this operation is the third period of the access time.

In a cyclic storage system the access time is divided into two periods. The first, known as the latency, is the time it takes for the memory box desired to become coupled in its turn to the reading and writing devices. The second period is the time required for the actual reading and writing. Here again, it might be necessary to include a time for the reading and writing devices to recover.

In progressive access systems, the access time is divided into the same periods as the cyclic access systems, namely the latency and the time for reading and writing.

PERMANENCE

The permanence with which data are retained in the storage system is another important factor. Some storage media are nonerasable, that is, the stored information cannot be altered without replacing the component used as a memory device. For example, to alter the information in a punched card, it is necessary to use a new card or a new column of the same card. A nonerasable storage

medium is useful for preserving records of a permanent nature. With this medium, it is possible to review the history of the computation program in detail. In data handling, there probably will be a certain amount of information which should be preserved as evidence. In digital control systems, it may sometimes be desirable to record some of the computations as performance data.

A disadvantage of nonerasable storage systems stems from the quantities of the storage medium that are consumed. A digital computer might operate at a speed which would require 2,000 references to the storage system per second. Of these references to storage, 20 per cent might be writing operations calling for the replacement of storage media. If the computer uses a 30-bit word, this would mean 43,200,000 bits recorded per hour. If they were recorded on punched tape with five bits per line and ten lines per inch, the computer would consume 72,000 ft of tape per hour.

Another aspect of the permanence with which data are recorded is the volatility of the storage medium. In a volatile storage medium positive steps must be taken to preserve the information stored. If these steps are not taken, the data will automatically erase itself. For this reason, valuable information which cannot be reconstructed easily should always be stored in a nonvolatile storage medium if there is any possibility of a power failure or other emergency preventing the continued preservation of the information. Also, when a volatile storage system is used, the computation program should be planned so that information can be transferred to a nonvolatile medium.

These basic principles will now be discussed as they apply to specific kinds of storage systems. In this discussion, storage systems will be grouped according to their mode of access, because this property more than any other influences the design of the rest of the computer. Table I groups the storage systems described in this article according to mode of access and permanence of storage.

CYCLIC STORAGE SYSTEMS

Cyclic storage systems are constructed on either the repeated reference principle or the regenerative delay principle. In repeated reference, the storage medium is moved cyclically past devices for reading and writing, so that each memory cell is available periodically in its turn. In regenerative delay, a writing device embodies the information as a disturbance in the storage medium. The storage medium propagates this disturbance during a definite interval of time to a reading device, which transmits the information back to the writing device, where it is rewritten. This procedure captures the information until it is needed. Each bit of stored information is therefore available periodically in its turn every time it reaches the reading device.

The memory cells used in the repeated reference principle are usually magnetic in nature. When this is the case, the storage system is erasable but nonvolatile. On the other hand, because the regenerative delay line principle depends upon rewriting the information every cycle, storage systems using this principle are inherently volatile.

MAGNETIC DRUM STORAGE

The magnetic drum storage system is the most common type of endless track memory. Its most important components are a rotating drum and a set of stationary heads. The drum is a nonmagnetic cylinder with a magnetic coating. The heads are assemblies of magnetic cores with coils wound around them. Near the magnetic coating of the drum, there is a small gap in the core.

In the writing operation, one of the coils is energized. This magnetizes the core. Because of the gap, however, some of the magnetic flux leaks out to the magnetic coating of the drum. This magnetizes the surface of the drum. The direction in which the surface is magnetized depends upon whether a one or a zero is to be recorded. A diagrammatic sketch is shown in Figure 1.

In the reading operation, the core picks up flux from the surface of the drum. The change in this flux generates an output voltage in one of the coils. This output is amplified and shaped to indicate the value of the binary digit in the memory cell which has just passed the head.

There are two ways in which the binary digits one or zero can be represented by magnetic patterns on the drum surface. The first of these is the return-to-zero (RZ) system and the second is the nonreturn-to-zero (NRZ) system. These systems are illustrated in Figure 2. In the RZ system, the magnetization goes from zero to positive or negative saturation and then back to zero again. In the NRZ system, there is a change in magnetization only when there is a change in the value of the digit stored. The magnetic pattern for NRZ is thus less complicated and information can be packed more densely in its storage medium. However, the NRZ system is slightly more complicated overall and is not as commonly used.

The construction of magnetic drums varies according to their applications. Drums have been built with diameters ranging from about 2 in. to 4 ft. The smaller diameter drums have shorter access times but they store less information per head. As a result, the cost per bit of storage capacity decreases as the drum diameter increases. The velocity of the magnetic surface relative to the heads tends to be the same within a given organization for all drum diameters once a standard practice has been established. Pulse repetition rates range from about 67 to 175 kc., the latter figure being associated with NRZ recording. Engineering Research Associates, one of the leaders in the magnetic drum field, has constructed several drums for RZ recording with a pulse density of 80 pulses per inch, a pulse repetition rate of 128 kc., and an axial distance between tracks of $\frac{1}{16}$ in.

In magnetic-drum storage systems, a reference to the storage system does not usually involve all the tracks at once. Instead, the tracks are divided into channels of one or more tracks and each word usually is stored in all the tracks of a channel. For this reason, some method of selecting channels is needed in making a reference to the storage system. In designing selection schemes, as much of the equipment as possible should be devoted to switching, reading and writing common to all tracks, and as little as possible should be duplicated for each track.

The equipment used for switching depends upon the time allowed. If the

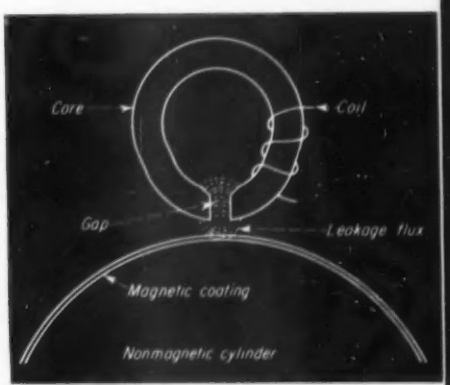


FIG. 1. Leakage flux from a gap in the recording head magnetizes the magnetic coating to store data in a magnetic-drum storage system.

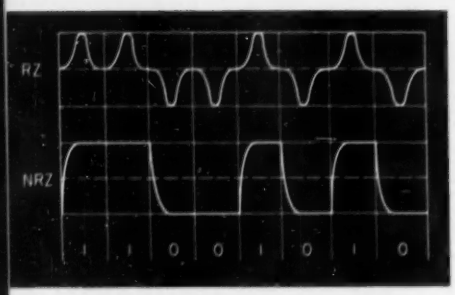


FIG. 2. Magnetization patterns for return-to-zero (RZ) and nonreturn-to-zero (NRZ) recording systems.

permissible switching time is short, some type of electronic gate is required. Where more time is available, relays are often used. One possible selection scheme is purely mechanical: the heads move axially from track to track. In this scheme, there is a great saving in the number of heads, but there are complications in the mechanical design.

An individual memory cell can be located by designating the track in which it is located and the angular position that the drum will assume when the cell is available. The track is located by the channel selection scheme. The angular position is identified by timing pulses, synchronized with the rotation of the drum, and distinguished from one another. The timing pulses define the locations of the memory cells definitely so that information can be read, erased, and recorded accurately. One method of generating the timing pulses is to use a special timing track on the drum.

Two methods of distinguishing the timing pulses from one another are possible. The first is by the use of address tracks, the second by an address counter that counts the number of memory cell sectors through which the drum has turned from sector zero. In both cases, the number indicating the actual angular position of the drum is compared with a number in an address register indicating the desired angular position. Where these numbers are equal, reading or writing takes place.

DRUM STORAGE SYSTEMS

There are several ways in which the memory boxes of a storage system can be arranged on a drum. Figure 3 shows serial, parallel and serial-parallel arrangements. Each of these is shown with and without interlace. These examples are based on an imaginary drum with eight storage tracks and sixteen memory cells per track. The tracks are represented by columns and the memory cells available for a given angular position of the drum are represented by rows. In all cases, the word 01011001 at address 1100 and the information designating that address are cross-hatched.

In the parallel arrangement, the bits of a word are all available at the same time. This requires more equipment than other arrangements, because all the tracks of a channel are in use at the same time. However, the parallel arrangement makes it possible to read and write information rapidly. The memory boxes could be arranged so that the addresses follow one another in their numerical sequence. However, an alternative scheme is to have the consecutive addresses separated from one another by a definite number of spaces. This is the interlaced parallel arrangement. It is used when the computer is incapable of the speed of the parallel arrangement and when the possible economies of other arrangements are, for some reason, not considered advantageous. In the interlaced parallel arrangement shown, the contents of the interlaced address tracks can be obtained by shifting the regular address tracks to the left. It is easy to modify the interlace simply by shifting the address tracks in this manner.

In the serial arrangement, the bits of a word follow one another in the same track. In the example, the three highest order bits of the address are obtained by track selection and the last bit by the address track. If any advantage could be gained, the bits for selecting the track and the bits for selecting the word within the track could be permuted as desired. Also, the least significant digits appear first. This arrangement is convenient for arithmetic operations. For data handling, it is sometimes more economical for the most significant digits to appear first. The serial arrangement is more economical than the parallel but it takes longer to transfer a word to and from the drum. Another alternative is the serial with interlace.

In the serial-parallel scheme, the tracks are grouped in channels that are

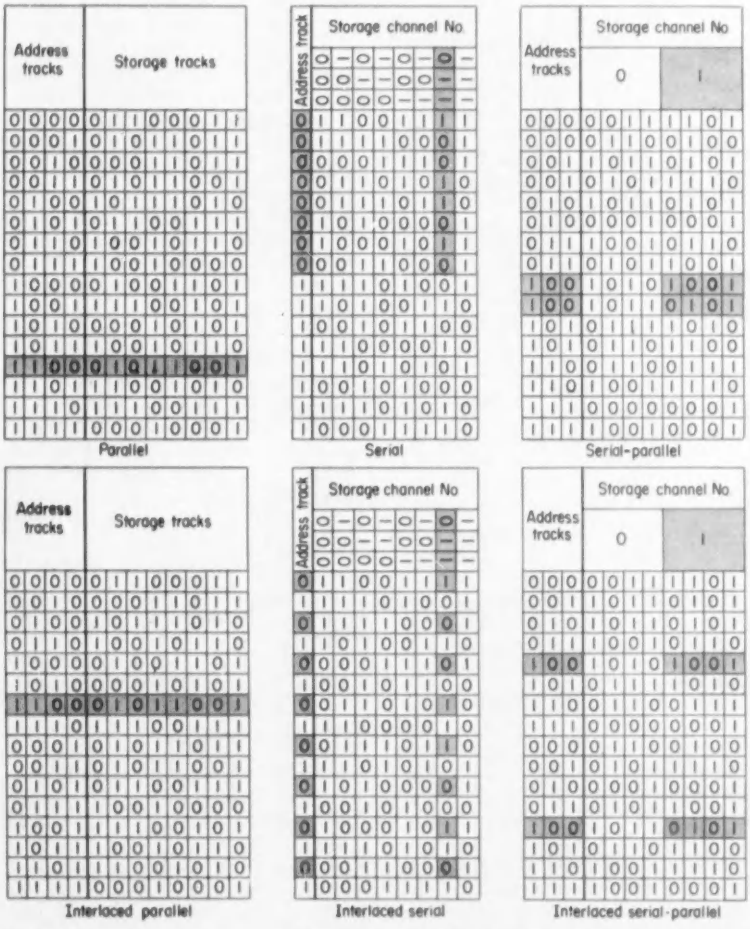


FIG. 3. Six storage arrangements for a drum with eight storage tracks and sixteen memory cells per track. In each case the word 01011001 at address 1100 is cross-hatched.

too small to hold an entire word in parallel. The words are divided into groups of bits called characters, which very often are binary-coded decimal digits. The bits of a character appear serially. This arrangement is more economical than the parallel but takes less time than the serial arrangement. Sometimes the bits of a character are staggered timewise from one another. This makes the storage system effectively serial in nature with a pulse repetition rate faster than the natural pulse repetition rate of the drum. Sometimes, the characters do not follow one another in consecutive sectors of the drum but instead are interlaced.

MAGNETIC TAPE LOOPS

An endless tape loop is another repeated reference cyclic storage system. Reading and writing is done as on a magnetic drum. But, because the magnetic drum is cylindrical, the length of a track is equal to 3.14 times the diameter. Thus the practical length of a track is limited by the size cylinder which can be housed. On the other hand, an endless tape loop can be bent around idlers so that a long tape can be housed conveniently. Storing more bits per head saves cost and the more compact arrangement saves space. The access time is long, however, because the long loop takes more time to pass the heads.

DISC STORAGE

There are two other systems that can store large quantities of data with relatively long access times. In one of these, the tracks are located on flat discs that can be selected automatically, juke-box fashion.

TAPE DRUM

In the other, a tape moves intermittently, the heads mounted on a cylinder and rotating continuously. When the tape is in a stationary position, a portion of its length is wrapped around the cylinder and the heads have access to that part of the tape. This part, together with the heads, then temporarily forms a cyclic storage system. The tape is moved to use information on another part without destroying the information just moved away from the heads. This allows a larger number of bits stored per head plus rapid access to a large number of bits.

REGENERATIVE DELAY LINES

The basic principles of the regenerative delay line are illustrated in Figure 4. Information is recorded in a medium. After a definite delay, the information is read. Then, in the normal course of events, the information is transmitted back to the recorder. This method stores the amount of information which can be handled during the delay time. Regenerative delay lines are used for short and medium storage times.

The output of the reader can be observed without interrupting the transmission of data to the recorder. To change the information stored, the transmission of data from the reader to the recorder can be interrupted and new information sent to the recorder.

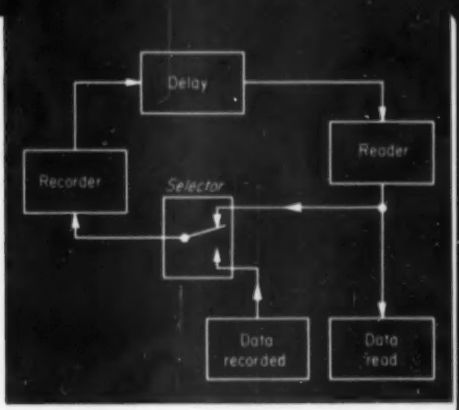


FIG. 4. Diagram of a regenerative delay line.

ACOUSTIC DELAY LINES

The most common kind of regenerative delay line storage system is the acoustic delay line. Here the delay is divided into a definite number of increments known as cell periods. During each cell period, the recorder writes a one or a zero into the acoustic medium by the presence or the absence of a shock. The shocks are then propagated through the medium to another transducer, which converts the shocks to electric pulses. The pulses are then amplified and shaped for transmission to either the recording transducers or the rest of the computer. The selector is a gating scheme that passes pulses from either the reader or the input to the delay line.

In the design of delay lines, the number of bits stored is limited by the properties of the storage medium. As the shock wave is propagated, it has a tendency to decrease in amplitude due to the damping capacity of the material and to become less sharp because of the nonlinearities of the material. The delay cannot be long enough for these effects to cause incorrect results. In addition, the rapidity with which pulses can be handled is limited. Thus there can be only a fixed maximum number of pulses during the allowable delay.

There are other problems. As temperature changes, the velocity of sound in the medium changes. Reflections cause trouble, too. The delay line must be designed so that shock waves reflected from its surfaces will not combine with the shock waves sent directly from the transducer to give an incorrect signal.

Mercury—The mercury delay line is used in a number of computers. The shock wave is of the dilation type. In the American computers in which it is installed, the pulse repetition rate runs from 1 to 4 mc. and the delay runs from about 300-400 microsec.

Quartz—The quartz delay line is available as a commercial component. In this component, the shock wave is a shear wave. The quartz storage medium can be in the shape of either a line for delays up to 100 microsec or a polygon for longer delays. In the latter case, waves are reflected from face to face of the polygon, following a long folded path from the input to the output. This makes the entire assembly compact. Magnesium has also been used as an acoustic material.

Magnetostrictive—Magnetostriction has also been used in the operation of delay lines. Coils are wrapped around the ends of a bar of nickel-iron, or other magnetostrictive material. A pulse through the input coil creates a magnetic field. This magnetic field develops stresses due to magnetostriction, which are propagated through the bar as a shock wave. When the wave reaches the other end, it generates a change in the magnetic field which is picked up by the other coil.

MAGNETIC TAPE DELAY

The double-headed magnetic track is another type of delay line. This storage device is not used for general storage but as a supplement to another storage system of longer access time. One head writes information on the surface of a magnetic drum or tape. The surface then moves to the other head, where it is read. It is then transmitted back to the write head. There is a mechanical limitation on the proximity of the heads; hence there is a minimum access time attainable by this method. In addition, there are mechanical problems involved in adjusting the heads relative to one another.

PARALLEL ACCESS SYSTEMS

Parallel-access storage systems are generally used where a combination of short access time and small capacity is required. Capacities are usually less than 2,000 words, but a coincident-current magnetic core memory has been designed with a capacity of 4,096 40-bit words.

Parallel-access storage systems are often part of compound storage systems. One part of a compound system is a large-capacity long-access-time

A RECTANGULAR HYSTERESIS LOOP . . .

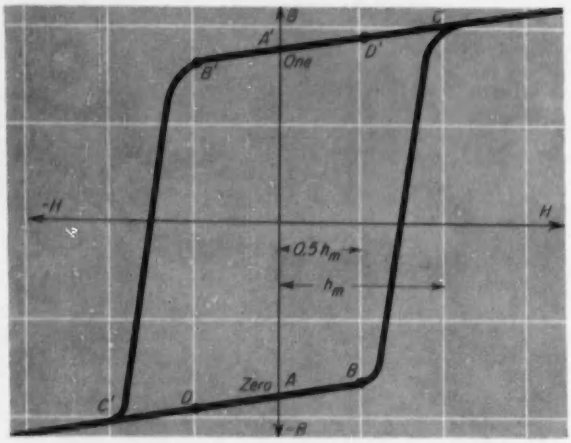


FIG. 5. Text (Magnetic Cores) explains how material with a rectangular hysteresis loop like this can store information.

. . . YIELDS THE CORE MATRIX MEMORY

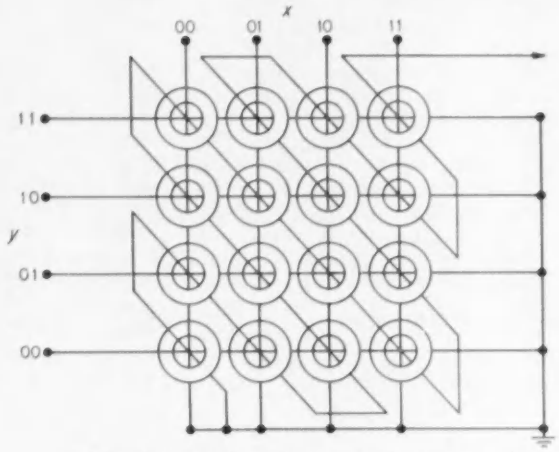


FIG. 6. A two-dimensional array of magnetic cores that can store 16 bits of information.

serial memory. The other part is the short-access-time parallel memory, which has relatively small capacity. Data can be transferred between the two storage systems.

Many of the new ideas for applying new physical phenomena to digital storage techniques attempt to prove themselves in the parallel-access field. The Williams tube was the first parallel-access storage system to develop popularity. However, its use is fading. At present, modified duplicates of computers with Williams-tube storage systems are usually made with coincident-current magnetic-core memories. These coincident-current memories are at present the most popular of this class and will probably continue to maintain their position for some time to come. But other systems are under development. Two of these newer systems will be discussed, namely the ferroelectric memory and the diode-capacitor memory.

MAGNETIC CORES

The coincident-current magnetic-core storage system uses as memory cells toroidal magnetic cores having rectangular hysteresis loops. An example of a rectangular hysteresis loop is shown in Figure 5. These cells are arranged in rows and columns and usually also in planes, as shown in Figure 6. When none of the wires passing through the core is conducting current, the value of H is zero and the core is in either state A or state A'. When it is in state A, it is storing a zero and when it is in state A', it is storing a one.

A system is designed so that (a) a current in only one of the wires passing through a core will not change the state of the core significantly and (b) a current through two of the wires will put the core into a state determined by the direction of the current. Thus, to record a one in the core for which x = 00 and y = 10, a signal must be applied in the proper direction to the line running down the column for x = 00 and to the line in the row for which y = 10. This would put a one in the desired core but would not affect the state of the other cores because current would flow in only one of their wires.

To show this in more detail, assume that, in Figure 5, current in one wire will give a value to H of 0.5 h_m, but that the combined effect of current will give a value to H of h_m. The cores for which $H = 0.5\ h_m$ will go from state A or A' to state B or D' respectively. When the current stops, they will return to approximately their original state. On the other hand, the selected core will get a value of H equal to h_m. In this core, there will be a change of state from A or A' to C. In both cases, the core will be in state A' after the current stops; i.e., a one will be stored.

The coincident-core memory is read by clearing the selected core to zero. If it stored a one before clearing, a core would change from state A' to state C', but if it stored a zero, the change of state would be from A to C'. In the first case, there would be a large change in the flux B, while in the second case the change in flux would be small. This change in flux generates a voltage in the third line passing through the core. If the voltage is large, it indicates a one, but if it is small, it indicates a zero. The third wire is therefore connected to a register so that a one is stored in the register if and only if a large voltage is generated. In order to preserve the information stored, a rewriting operation automatically follows a reading operation. This increases the access time slightly but it relieves the programmer of the burden of preserving stored information.

Even though the change in flux is small when the state of the core changes from A' to B' or from A to D, there is nevertheless some voltage built up by this change in flux. Since there is a large number of cores subject to this small change in flux, the third wire in Figure 6 is threaded through the cores so that the voltages generated will tend to cancel each other out.

The writing operation can be done in either of two ways. In the first method, the direction of the current in the wires passing through the selected core could depend upon whether a one or a zero is to be selected. In the second method, the core is cleared to zero before writing takes place. Then two wires select the core and supply enough current to write a one in the core. However, there is a third wire through which current flows in the opposite direction if a zero is to be written. This third wire reduces the value of H in the selected core enough to prevent a significant change in state.

In the previous discussions, there was frequent reference to the phrase

"significant change in state". When the core is forced from state A' to state B' and then is allowed to return to state A', the state to which it will actually go is slightly different from A'. It will go to a state where H again equals zero but where the value of B is slightly reduced. In the design of memory systems of this type, precautions must be taken to make sure that the value of B does not become so small that the change of state from A' to C' is too small to provide the signal necessary to change the state of the core.

When the coincident-current magnetic-core memory system is used, it is the usual practice to divide the binary digits of the address into two groups. The first group indicates the value of x and the second the value of y. There is usually one plane for each binary digit of the word. Then the wires associated with each specific value of x or y for all the planes are connected together. In this way, all the bits of a word are read from the same selection devices. During writing, all the selections are made by the same selection devices but the discrimination between ones and zeros is accomplished by a third wire associated with the particular bit.

WILLIAMS TUBES

The Williams-tube memory system uses a cathode-ray tube to store a two-dimensional array of memory cells. The tubes are usually used in parallel with one of the bits of a word in each tube. In this case, an address is represented by two numbers—an x-coordinate and a y-coordinate. An alternative arrangement is to use the x-coordinate to represent the address of a word whose bits are a line along the surface of the tube.

Each memory cell is composed of two neighboring areas. One of these areas has a higher positive charge than the other. The location of the higher positive charge determines whether a one or a zero is stored. When a beam of electrons is focused on one of these areas, that area becomes the more highly charged.

To read, the beam is focused on one of the areas so that the memory cell is cleared to store a zero. If there is a change in state because the cell held a one before it was cleared, the change of state will be sensed, causing a one to appear in a register. If the cell contained a zero originally, there will be a zero in the register.

Since reading clears the memory cell to zero, it is customary to include an automatic rewrite in the reading operation. Writing is accomplished by focusing the beam on the proper spot of the memory cell.

The Williams tube is a volatile memory system. The charged areas of the memory cells tend to lose their charge. Therefore, when this type of memory is used, there must be a plan for reading and rewriting the contents of each memory cell at intervals sufficiently short to prevent loss of information.

The Williams tube is now being replaced in many computers by coincident-current magnetic-core memories. These memories perform most of the functions of the Williams tube at about the same operating rate and on the whole are easier to construct and maintain.

FERROELECTRIC

Ferroelectric storage systems are under development as proposed computer components. These devices use ferroelectric hysteresis in approximately the same manner as magnetic hysteresis is used by magnetic cores. This type of storage system will be much more compact than the magnetic core. Other objectives are reduced cost and power consumption and increased operating rate. However, this storage device is something to be considered as a possible future development rather than as a current computer component.

DIODE-CAPACITOR MATRICES

Another parallel-access storage system is the diode-capacitor matrix. This system is more expensive than the coincident-current magnetic-core system. However, if the costs of some of its components are reduced and if the operating rate is increased by further development work, this type of storage system might become economical.

The principles of operation are illustrated in Figures 7 and 8. The words are arranged in a two-dimensional array with the individual bits along a third dimension. A particular word is designated by a pair of simultaneous values of x and y.

As an example of the method of selecting words, consider the word for which x equals 0 and y equals 0. To select this word, set the voltage on line E_x at minus 10 volts and the voltage of line F_x at plus 10 volts, leaving the voltage on line E_1 at plus 10 volts and the voltage on line F_1 at minus 10 volts. This makes current flow from line F_x to line E_x. However since line F_x has the same voltage as E_x, no current flows from F_x to E_1. For a similar reason, no current flows from F_1 to E_x. Finally, no current flows from E_1 to F_1 because of the rectifier. Thus, these changes in voltage in lines E_x and F_x cause current to flow in the primary of only one transformer, namely the transformer associated with the word for which x equals 0 and y equals 0.

When current flows in the primary winding of this transformer, voltages, generated in the secondary windings, make the voltage in lines A_{xo} and C_{xo} equal to zero. This makes the voltages at B_{xo} and B_{ox}, zero also. In bit zero, the voltage was originally plus 1 volt. This causes current to flow from B_{xo} to C_{xo}. However, the voltage across the condenser drops slowly so that the voltage of D_o approaches minus 1 volt. This voltage drop is sensed by the amplifier which, after a slight delay, further reduces the voltage at D_o to minus 2 volts and holds it at that voltage until the condenser is charged, so that the voltage at B_{xo} has settled back to zero. At this time, the voltages generated in the secondary windings of the transformer die out. Then C_{xo} is at plus 4 volts and A_{xo} at minus 4 volts. At the same time the voltage of D_o returns to zero, thus causing the voltage at B_{xo} to rise to plus 2 volts.

With A_{xo} at minus 4 volts, C_{xo} at plus 4 volts, and B_{xo} at plus 2 volts, current from B_{xo} to C_{xo} or from A_{xo} to B_{xo} must pass through the back resistance of the diode. Because this is a high resistance, the rate at which the condenser discharges is slow.

Before the condenser discharges too much, this cycle must be repeated to restore the voltage at B_{xo} to plus 2 volts. This places a limit on the size of the memory. The maximum time between restoration divided by the time per restoration gives the maximum number of words which can be preserved.

In this memory system, a positive voltage at B can represent a one and a negative voltage at B can represent a zero. If the voltage at B_{ox} is negative, the cycle will be similar to that at B_{xo} except for signs. This is shown at the bottom of Figure 8.

PROGRESSIVE-ACCESS SYSTEMS

Progressive-access storage systems are characterized by a small number of reading and writing devices which can be coupled by mechanical motion to a large number of memory cells. This makes the cost per bit small and the access time large. For this reason, they are usually used as input-output equipment or as auxiliary memories.

PUNCHED CARDS

The most common storage device of this nature is the punched card. The cards are placed in a stack and are removed from the stack one at a time in succession. The memory cells on the card are positions in which a

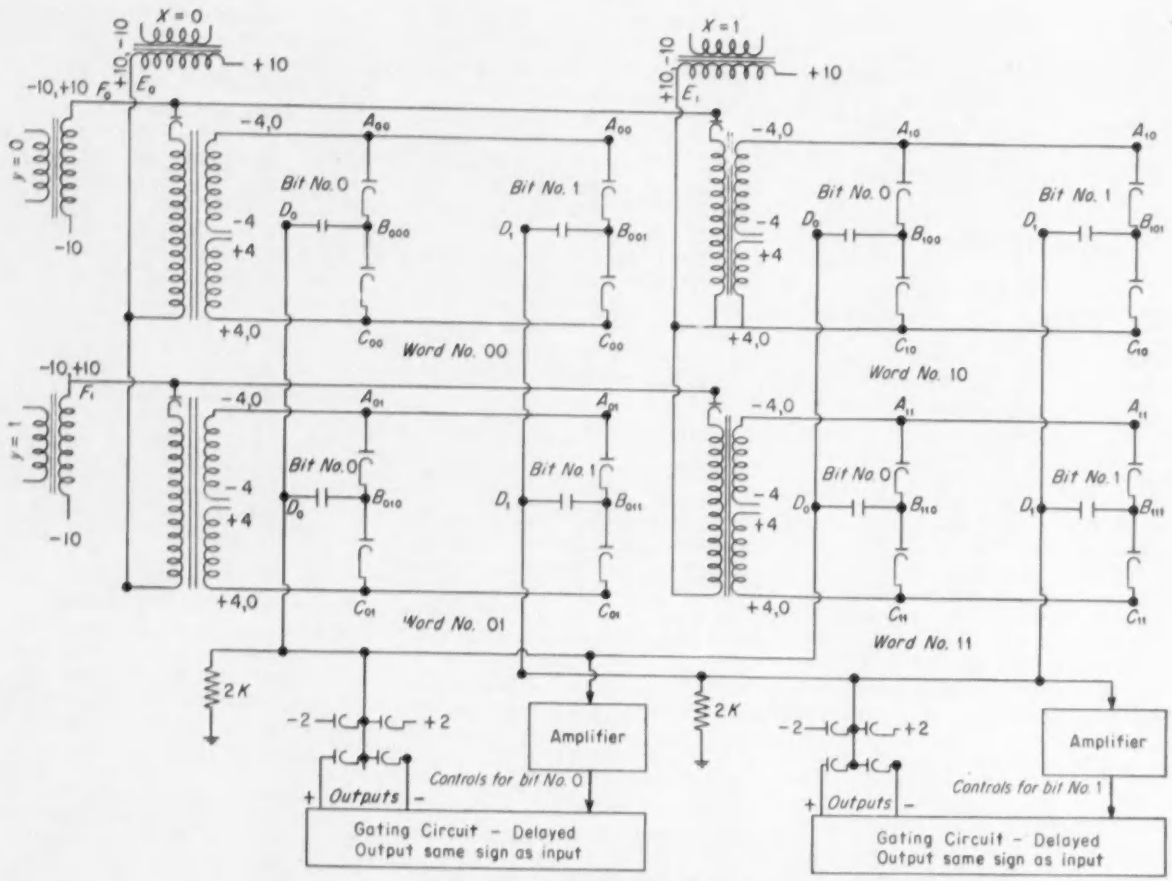


FIG. 7. A 4-word, 2-bits-per-word diode-capacitor matrix storage system.

A DIODE-CAPACITOR MATRIX STORAGE SYSTEM . . .

AND ITS SIGNALS

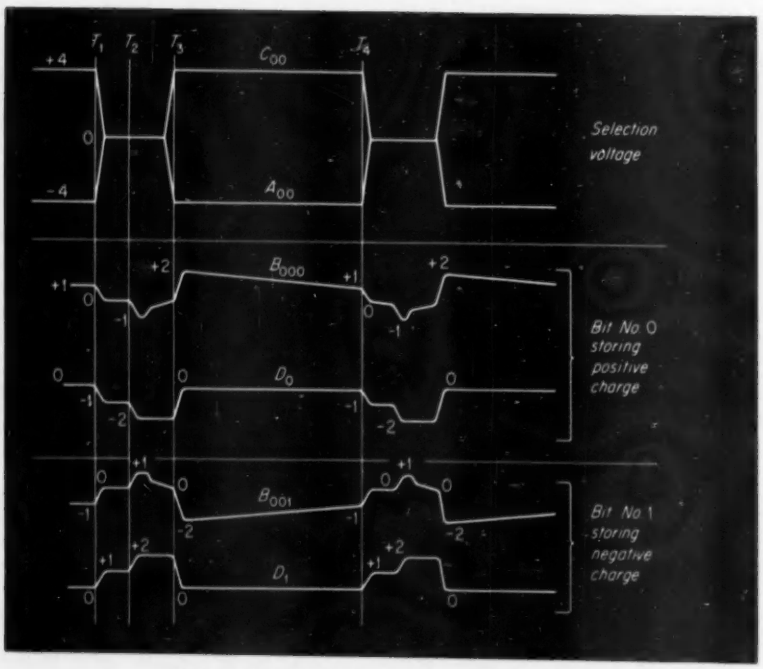


FIG. 8. Signals in the diode-capacitor matrix.

hole may be punched or not. These memory cells are then grouped in columns, each column being used to represent a numeral from 0 to 9 or a letter of the alphabet. The best known of these is the IBM card, which usually represents a character by holes in two or less of twelve possible hole positions, and therefore uses only a small fraction of its capacity. If any combination of bits were allowed in the memory cells of a column, there would be 4,096 possible symbols.

Because the punched card is a nonerasable storage medium, its usefulness for internal storage is limited. However, it is widely used for input and output.

KEYSORT CARDS

While punched cards are ordinarily used as a progressive storage medium, the Keysort card is used as a parallel access device. This card has round holes punched near its edges. Some of the positions are notched to remove all the material between these holes and the edge of the card. Each position is therefore a memory cell which stores a one or a zero depending on whether the position is notched or unnotched. If the cards are stacked together, there will be a hole through the stack for each position on the card. If a rod is passed through one of these holes, it will pass through the cards that are not notched in that position but will clear those that are notched. The rod can therefore be used to separate the notched cards from the unnotched ones in a single manual operation.

PUNCHED TAPE

Another common form of progressive access device is the tape or wire. Punched tape is the oldest of these and probably in the most general use. Holes are punched across the tape in rows, about ten lines to the inch. They can be read by electric contacts or by photocells. An alternative system is to replace the holes by black marks on a transparent tape. Photographic film can be used for this purpose. Storage systems of this nature are used almost exclusively for input-output because of their nonerasable nature.

MAGNETIC TAPE

Magnetic tape or wire, being erasable, can be used not only for input-output but also as an auxiliary memory. Here the data are recorded on a tape in much the same way as they are recorded on a drum. The density of recording on tape is about the same as on a drum, although some laboratories claim to be able to record as many as 600 bits per inch in a single channel. In the Univac, extensive use is made of tape as an auxiliary storage device. Metal tape is used in devices referred to as Uniservos, which communicate with the central computer in accordance with instructions in the program. This idea is also used in other computing systems.

OTHERS

An effort is being made to take advantage of the mechanical motion between the storage medium and the reading devices without undergoing such long access times. This has lead to the development of a number of systems with progressive access within channels but with heads that can be transferred mechanically from channel to channel.

The earliest in this field was the notched-disc memory developed by the U. S. Bureau of Standards. A number of notched discs are arranged in a toroidal array with the notches in all the discs turned toward the center. Heads mounted on an arm swing through the notches to the selected disc. When the heads are in position, the selected disc is turned past the heads so that the desired information can be used.

Another development is the Potter random access memory. Magnetic wires are mounted parallel to one another in frames. The frames, in turn, are mounted parallel to one another in racks. Access to a particular word is obtained on a three-dimensional basis —a parallel-access selection of the frame and the wire within a frame and a progressive-access selection along a wire of a particular word. After selection, a single head reads the wire.



FRANKLIN H. FOWLER JR.

Mr. Fowler was graduated from Yale University in 1938. Most of the earlier part of his engineering career was devoted to theoretical applied mechanics, mainly in stress analysis and vibration. Since 1950 he has been specializing in logical design and system studies of real time and other digital-computing and data-handling systems. His first job in the digital-computer field was with Engineering Research Associates (now part of Sperry Rand). Since then he has worked for the Jacobs Instrument Co. and as an independent consultant. While in consulting work, he prepared this article and presented to the ACM a paper describing a magnetic-drum sorting system. At present he is a professional engineer in the Commercial Electronic Products Div. of RCA.

Frequency-Responsive Speed Control

R. E. WEBER, Weston Electrical Instrument Corp.

The frequency-responsive tachometer measures the frequency of an ac generator's output to indicate speed. This accurate source of control signals is relatively independent of voltage variations due to the tachometer generator.

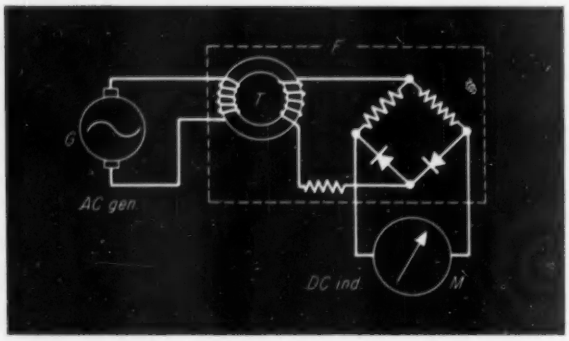


FIG. 1. Basic circuit of the frequency-responsive tachometer.

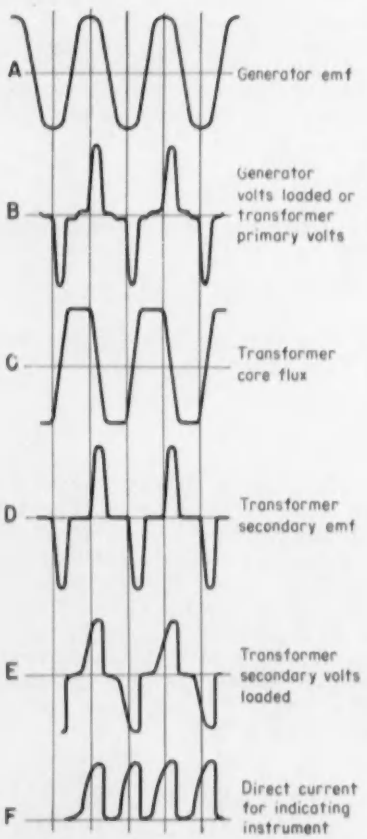


FIG. 2. Voltage waveforms in the frequency-responsive system.

Electrical tachometers have been used for speed measurement and control for more than half a century. The first, developed by Dr. Edward Weston in 1896, consisted of a generator, which developed a voltage proportional to speed, and a permanent-magnet movable-coil voltmeter calibrated in terms of speed. The recent development of the frequency-responsive tachometer was a major stride in the field of electrical tachometry.

The frequency output of an ac generator depends upon the number of its magnetic poles and its speed of revolution. Consequently, the ac voltage output of such a generator has a frequency exactly proportional to speed. A means of directly indicating this frequency to sufficient accuracy would make possible a tachometer completely free of voltage errors due to the tachometer generator. Prior to the development of the frequency-sensitive network used in the frequency-responsive tachometer, the closest approach had been an electronic counter. This, however, has several disadvantages when used as a tachometer, such as size, power consumption, and slow indication.

Figure 1 diagrams the essential parts of the frequency-responsive tachometer. G is the ac generator, which generates a voltage at the frequency to be measured, and powers the circuit. The frequency-sensitive network, *F*, converts the output of the generator into a current proportional to its frequency. A milliammeter, *M*, indicates this current in terms suitable to the application (rpm, fpm, ips, etc.).

The key to the operation of this system is *T*, a transformer wound toroidally on a core of magnetic material with a rectangular hysteresis loop. This core saturates at a relatively low primary voltage. At each cycle the core flux changes from saturation in one direction to saturation in the other direction. This change causes a voltage in the secondary winding, which has an average value proportional to the frequency of the impressed voltage. Figure 2 shows waveforms in the circuit. More pulses per second means a higher average current in the output circuit of the transformer. The pulses are rectified, and then averaged by *M*, a p-m movable-coil instrument indicating average current. Thus, indicator readings are a direct function of the frequency output of the generator and the whole system is relatively insensitive to voltage variation.

Accuracy

This approach is more accurate than conventional voltage-responsive electrical tachometer systems. For example, ac generators can be manufactured in production quantities with a repeatability of better than plus or minus 0.25 per cent and an interchangeability

of 1 per cent. Add to this a 1½ per cent rectifier-type voltmeter and the system has an overall accuracy of about plus or minus 2½ per cent of full-scale indication, with a repeatability of plus or minus ¾ per cent. The use of a frequency-responsive network eliminates the inaccuracies in the generator, resulting in measurements with less than plus or minus 1½ per cent error and with a repeatability of better than plus or minus ½ per cent. Special techniques and 0.1 per cent indicating instruments give speed measurements accurate to better than plus or minus ¼ per cent.

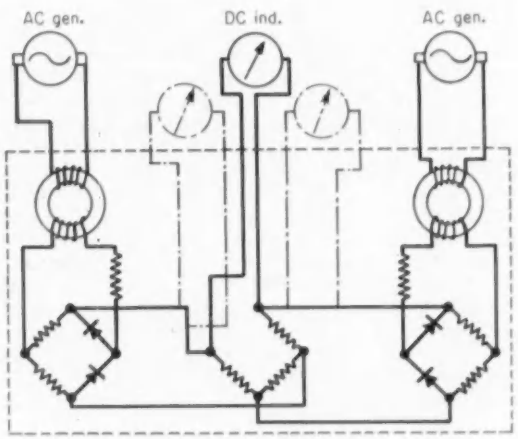
The initial application of this system was for differential speed measurement, Figure 3. It has also been used for straightforward speed measurement, as already shown in Figure 1, and for electrical zero suppression of instruments, as in Figure 4. In this last case, a reference frequency source, usually the 110-v 60-cps commercial supply, is compared in a differential circuit to the frequency of an ac generator. Resistor R varies the effect of the reference to calibrate the meter. Proper choice of components permits suppression of as much as 96 per cent of the full-scale value.

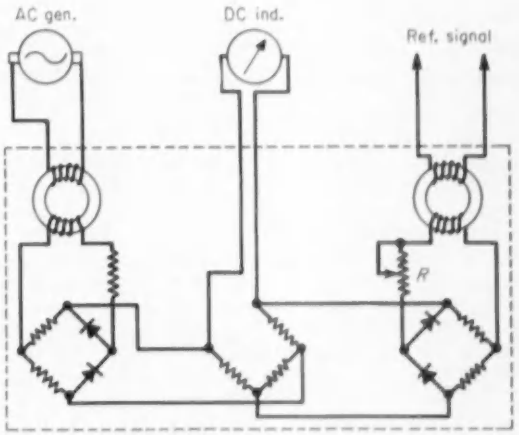
Speed Control

The frequency-responsive tachometer can also be used for precise speed control. Figure 5 is a simplified diagram of the speed control system for the secondary take-up reel of a wire-insulating machine. In this machine, an insulating material is continuously extruded onto a wire moving at a few thousand feet per minute. The insulated wire is wound onto take-up reels for shipment. As the working take-up reel is filling, an empty "secondary" take-up reel is driven so that its surface speed matches the linear speed of the wire. When the working reel is full the wire is cut and transferred "on-the-fly" to the secondary reel. The speeds must be very close to prevent snarling or breaking the wire.

When working, a reel's speed is controlled by a slipping magnetic clutch to provide proper tension in the wire. The control system of Figure 5 is concerned only with the speed of a reel when it is secondary. This system uses a frequency-responsive differential circuit like that of Figure 4 to operate a zero-center instrument relay. In Figure 5, the instrument relay, S_1 operates a motorized rheostat, V, via power relays S_2 and S_3 to increase or decrease the speed of the secondary reel motor.

In starting the machine, the secondary reel speed S_R is increased manually until meters M_1 and M_2 indicate the proper speed match with the wire speed S_W. Then R_1 is adjusted until S_1 indicates zero. S_4 is then thrown to "on" and the control system takes over. Any deviation in speed relationship will initiate corrective action. If S_R increases, S_1 will make contact on the high side, actuating S_2. This in turn energizes time-delay relays S_3 and S_4. S_4 resets the magnetic contacts in S_1, and S_4 applies voltage to the drive motor of V for a given time. Rotation of V changes the voltage applied to D in the direction to cause S_R to decrease. This sequence recurs until S_R has dropped to within the proper relationship with S_W. At this point the transfer between the working and secondary take-up reels may take place. Such a system permits control of the reel speed, S_R, within plus or minus ¼ per cent, and forestalls tangles or breaks.





DIFFERENTIAL FREQUENCY-RESPONSIVE CIRCUITS AND A SPEED-CONTROL SYSTEM

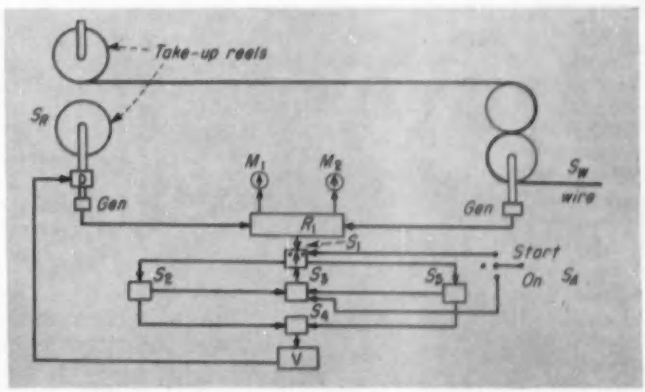


FIG. 3 (left above). Differential speed-indication circuit.

FIG. 4 (right above). Electrical zero-suppression circuit.

FIG. 5. A closed-loop contactor servo using differentially-connected frequency responsive tachometers (see text).

IDEAS AT WORK

Compound Modulation Improves Data Storage

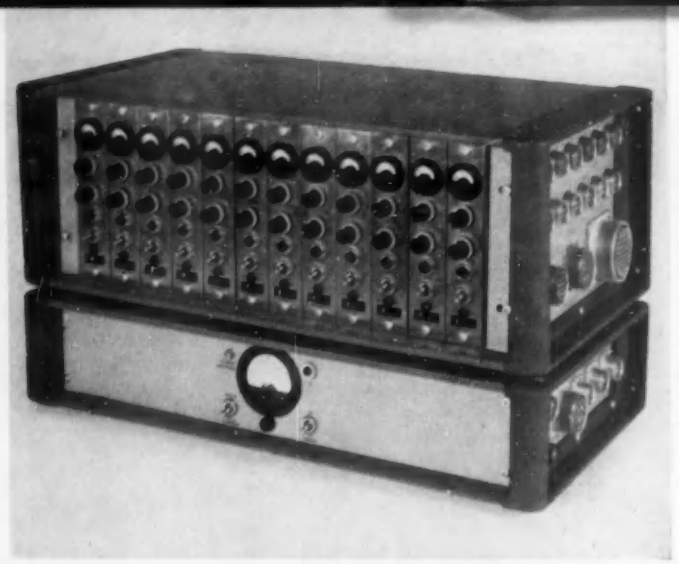


FIG. 1. Plug-in construction of this CEC DataTape signal modulator allows each of twelve channels to amplify and code signal input voltages for either compound modulation, direct recording, or pulse-duration modulation.

Magnetic-tape recording systems store test data for subsequent data processing. These transducer data must be recorded in a form that will permit accurate and automatic recovery of voltages analogous to each measured phenomenon. The usual methods, amplitude modulation or frequency modulation, present certain difficulties, but compound modulation surmounts them.

RONALD L. BENTLEY,
Consolidated Electrodynamics Corp.

Amplitude-modulation storage of test data from transducers introduces amplitude errors of up to plus or minus 10 per cent due to the characteristics of the tape; and its frequency response does not extend down to dc signals. Frequency modulation overcomes these disadvantages, but introduces zero drift, which may be caused by drift in dc amplifiers, in the f-m-oscillator center frequency, or in the f-m discriminator. Zero drift may also be the result of variations in average tape velocity, which, in turn, cause a spurious signal.

Compound Modulation

What is compound modulation? Basically, this technique combines the time-proved advantages of amplitude modulation and frequency modulation, and eliminates their major disadvantages. C-m will be compared below with f-m, since these methods most nearly overlap in frequency response for a given tape speed.

More specifically, compound modulation combines suppressed-carrier amplitude modulation with frequency modulation. A twelve-channel modulator is shown in Figure 1. The demodulator normally associated with carrier-amplifier systems has been deferred until playback in the c-m system. This locates all demodulation electronics in the playback equipment.

In this system a stabilized oscillator applies its locally generated signal to a bridge-type transducer. (With the addition of a plug-in low-level inverter to the c-m modulator the channel can handle outputs from transducers that cannot in themselves be carrier-excited. Typical of this class of instruments are thermocouples, resistance thermometers and dc-excited potentiometers). When the transducer experiences an input to cause imbalance, the bridge's output will be a suppressed-carrier amplitude-modulated wave. Likewise, when the transducer input is exactly at its reference point, the bridge balances and there is no output wave. Thus the amplitude of output envelope is proportional to the magnitude of the input signal, and the phenomenon's rate of change is represented by the rate of change of the carrier envelope. The sign of the input is carried in the phase relationship between the carrier source and the carrier of the modulated wave. A conventional ac amplifier, with its inherent reliability and freedom from drift, amplifies the low-level modulated wave form to a suitable level.

This amplitude-modulated carrier signal in turn modulates a frequency-modulated oscillator. In the absence of an incoming signal to the frequency modulator, the oscillator has a fixed frequency known as the f-m center frequency. When a modulating signal comes from the carrier amplifier the frequency of the f-m modulator changes about its center value at a rate equal to the carrier frequency. These frequency deviations depend on the amplitude of the incoming signal. The rate at which the peak frequency deviation varies is determined by the phenomenon frequency sensed by the transducer. As the last step in the c-m technique, a magnetic tape records the f-m oscillator's output.

Recording Pressure Variations

The compound modulation technique can be applied, for example, where a variation in pressure is to be recorded. Figure 2 shows signal waveforms at various points in the system. Assume the pressure transducer (Figure 2A) has a full-scale range of 0 to 100 psi, and that the pressure rises suddenly at time t_1 from zero to 50 psi. Starting at time t_2, variations of plus and minus 10 psi occur around the average pressure (50 psi) at a 100-cps rate.

Figure 2B shows the output of the bridge transducer for the signal variations of Figure 2A. Here, with a 1,500-cps carrier applied to the bridge, the net output is zero until time t_1, when it consists of a 1,500-cps low-level sig-

nal. The amplitude of the envelope remains constant until t_2. After t_2 the envelope varies at a rate of 100 cps, corresponding to the frequency of the pressure applied to the transducer. Thus the output shown in Figure 2B is an amplitude-modulated suppressed-carrier signal.

The amplified signal of Figure 2B, with its basic form unchanged, is applied to an f-m oscillator with a nominal center frequency of 10.5 kc. The resulting oscillator output, to be recorded on the magnetic tape, is shown in Figure 2C. Here the oscillator frequency swings about its center frequency at a rate of 1,500 cps. Full scale input causes the f-m-carrier frequency to change by plus or minus 20 per cent of its center value. Thus, in this case, the applied pressure determines the amount of swing and the f-m-carrier frequency remains constant at 10.5 kc until t_1. After this time the f-m carrier swings about its center frequency at a 1,500-cps rate with a deviation of plus or minus 10 per cent (half of full scale) of the f-m-carrier-center frequency. After time t_2 variations from the center frequency rise to a maximum of 12 per cent and fall to a minimum of 8 per cent. Thus a plus and minus 10 per cent variation of full-scale pressure swings the center frequency from 8 to 12 per cent and back to 8 per cent at a 100-cps rate.

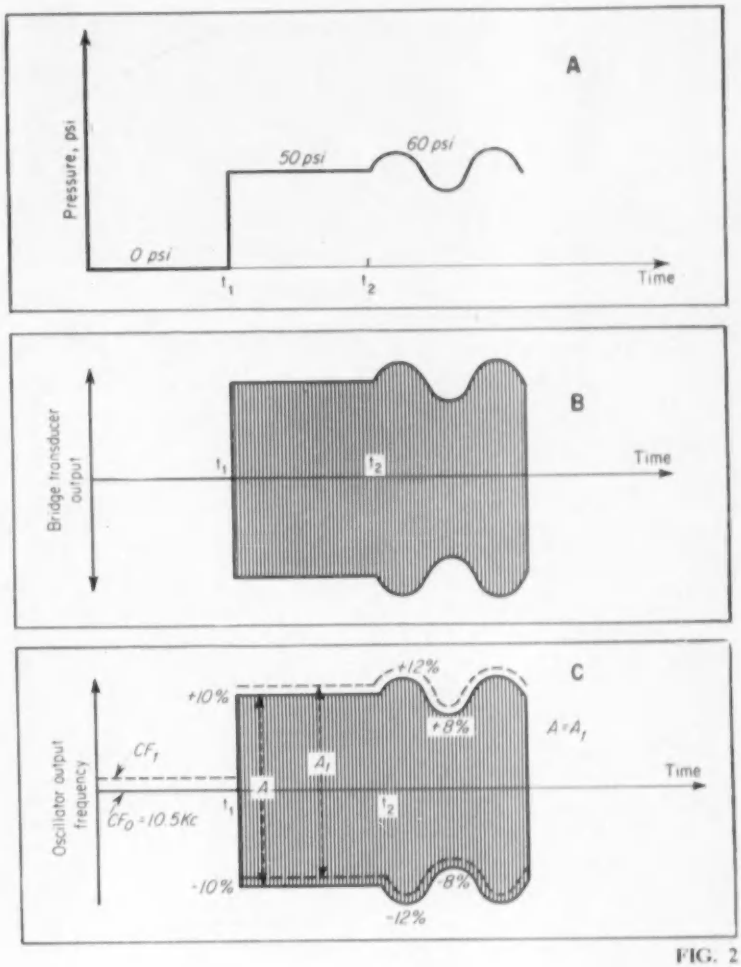
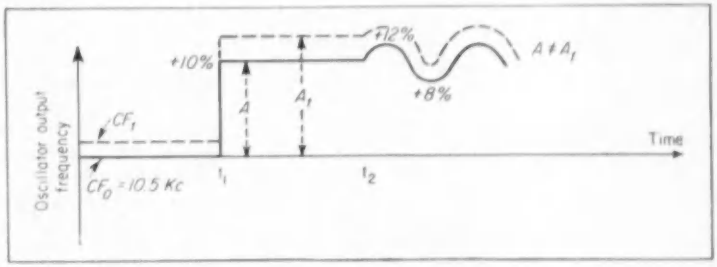


FIG. 2

FIG. 3



Improved Accuracy

Assume the f-m-center frequency CF_0 (in Figure 2C) drifts to some new center frequency, CF_1. Since the intelligence of the data is carried in the total frequency deviation and not in the instantaneous frequency deviation, the shift in center frequency has no effect. That is, when A equals A_1, no loss of accuracy occurs.

Now consider the pressure variations of Figure 2A applied to a system with frequency modulation only. In f-m the transducer signal drives the oscillator (center) frequency higher or lower depending on the polarity of the applied signal. Thus the amount of deviation of the f-m oscillator from its center frequency is proportional to the applied signal, and the rate of change of the frequency deviation represents the rate of change of the applied signal.

As in the case of c-m, the frequency-modulated oscillator has a center frequency of 10.5 kc, and the frequency remains constant until time t_1. At this time the oscillator frequency shifts to new values differing from those of the center frequency by plus or minus 10 per cent, and at time t_2 it shifts from a maximum of 12 per cent to a minimum of 8 per cent at a 100-cps rate.

But analysis of Figure 3 shows there is a loss in accuracy. In f-m systems, the intelligence of the data is carried in the instantaneous frequency deviation from a fixed center. It can be readily seen that a shift in the center frequency to some new value means that A no longer equals A_1. Therefore, in demodulating the f-m signal the output will no longer be proportional to the transducer input.

Demodulating the C-M Signal

The playback instrument for c-m signals requires two stages of demodulation. The first stage uses a frequency discriminator to recreate the original amplitude-modulated suppressed-carrier signal. A phase-sensitive demodulator used in the second demodulation generates the analog of the original pressure applied to the transducer. This stage also uses a reference signal in phase with the original carrier signal, which was applied to the transducer. The reference signal, recorded simultaneously with the data, also determines the proper polarity of the demodulated signal.

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Relativity is the keynote in the design of a new, high-speed function generator developed by The Stephen-Douglas Co. of Santa Monica, Calif. The Phosiac (Photographically Stored Information, Analog Comparator), ignores a variety of hard-to-control factors to produce high precision.

A 1½-in.-sq photographic plate is the heart of the machine, which is intended for analog computers and for "universalizing" aircraft simulators. It generates Z as a function of two independent inputs, X and Y, and can be easily given a new information source (the Data Plate). Because of this, aircraft simulators using the device can be switched quickly to display the characteristics of a variety of aircraft.

Errors are inevitable with any attempt to establish an absolute correlation between photographic emulsion gray scale and voltage because of the electrical, optical, and chemical variabilities of the read-in and read-out apparatus. But this device detours these difficulties by correlating the emulsion density of the XY intersection point in the information area of its plate with the location of a corresponding density in a strip that has a linear variation in gray. The location of this corresponding density forms the basis for the Z voltage output.

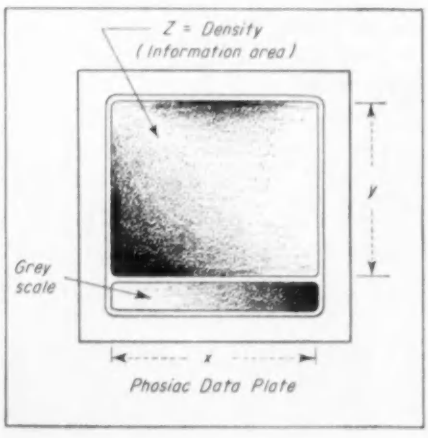
While the input X and Y voltages locate one beam of a two-gun cathode-ray tube (crt), an electronic servo (with input from a photomultiplier sensing this beam's spot through the Data Plate) positions the second beam along the lineal gray scale until its effect on the photomultiplier is the same as the first beam's. The deflection voltage (linearized) for this second beam then becomes the Z output. The block diagram illustrates the circuit. A single photomultiplier detects the two light spots projected through the Data Plate. Each spot is modulated at 5 kc, with a 180-deg phase difference. The comparator circuit, by detecting the predominant phase of the photomultiplier's output, drives the second beam of the crt to a condition of no-phase amplitude difference. Harmonics above 5 kc are ruled out in the phase detector.

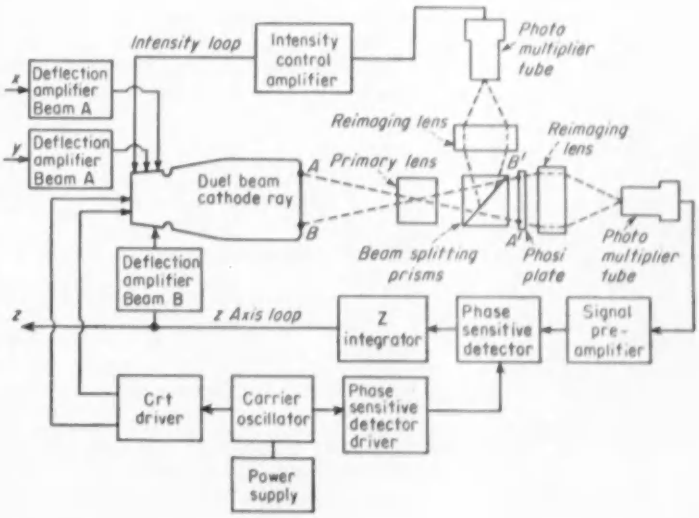
The two light spots are also intensity-controlled by a negative feedback loop using a second photomultiplier placed in front of the Data Plate. The reimaging lenses seen in the block diagram distribute the output of the primary lens over a large fixed area of each photomultiplier to circumvent the possibility of sensitivity variations across each face.

The Data Plate is prepared by means of a punched-tape-controlled automatic master film maker which produces a total of 300 scans. It takes from 3 to 4 min to prepare the film.

Because the Phosiac's operating speed is not limited by the inertia of any of its components (as are electromechanical function generators) it can perform at 100 cps without difficulty, and can be pushed to 1,000 cps. Under study at the present time is a motion-picture-type film transport that will make the output a function of three independent variables.

The Phosiac was developed for the Air Force under a 1954 contract.





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Error Analysis Proves Digital-to-Analog Conversion can be Precise

Application of an important technique—error analysis—demonstrates the accuracy of a 17-bit digital-to-analog converter by showing up probable peak errors of one to two parts in 100,000.

FRANK BRADLEY, Bradley Associates

The function of a digital-to-analog converter is to transform a given number to an exactly equivalent analog form. The relay-operated voltage divider (ROVD) is the basic high-accuracy digital-to-analog converter. A common instrumentation of the ROVD (type 1) utilizes two "sticks" of matched pairs of resistors whose sequential resistance values depend upon the numerical system of the digital output. One set of resistors is connected above a pick-off point and an identical set below, Figure 1A. The digital number operates relays associated with each resistance pair, shorting out either the resistance above the pick-off point or the resistance below.

In a second instrumentation (type 2), a constant-current source drives a single resistance stick, Figure 1B. Individual resistors are series-connected and may be shorted out by relays under control of the appropriate digits.

Accuracy

Both types are about equally accurate. Type 2 has the simpler switching and only one set of resistors, but requires a constant-current source. Using a suitable constant-current drive, however, the converter can drive appreciable loads directly. Constant-voltage-driven converters are sensitive to loading and must be either isolated or compensated.

Factors affecting performance:

- resistor accuracy
- shorting resistance (lead resistance and relay-contact resistance)
- transient resistance effects (at high readout speeds)
- calibration accuracy and departure of constant current source from ideal (or loading of the constant-voltage-driven converter)

The quantizing error due to a finite number of digits, while necessary in system consideration, is not properly attributed to the converter. Thus, besides the ROVD errors, a quantizing error of one-half the resolution must be considered.

The setting of the resistance stick is the series resistance under a given relay condition. This setting is subject to an error dependent upon resistance accuracy. Figure 2 indicates three possible types of error distribution. For a curve-(1) distribution the error at any setting is a constant per cent of the total stick resistance. This places a loose tolerance on all but the few larger resistors. A curve-(3) error-distribution provides at any setting an error that is a constant percentage of the setting rather than of total resistance. This places an identical tolerance on all resistors. It is extremely difficult to realize such an errror distribution.

Curve (3) represents an intermediate solution. This curve is a plot of the error distribution of a commercially available 17-digit binary resistor set manufactured by the Julie Research Laboratories. This unit permits synthesis of resistance values between 0 and 131,071 ohms in 1-ohm steps. The error curve accuracy may be expressed as:

$$\text{Peak error} = \frac{15\sqrt{x} + 0.16}{10^4} \quad \text{per cent of } R_{max}$$

The following analysis is based upon this specification. Note that x runs in one-ohm steps between zero and unity, which corresponds to 131,071 ohms.

Error accumulation near unity is limited in the same way as the build-up near zero because the resistance is varied by switching the smaller, more accurate (as per cent of full scale) resistors. Thus, referring to Figure 3A, if e_r is the error at full scale, the error distribution is restricted to the shaded region. Figures 3B and 3C denote the limiting cases of error distribution.

Type 1

Referring to Figure 4:

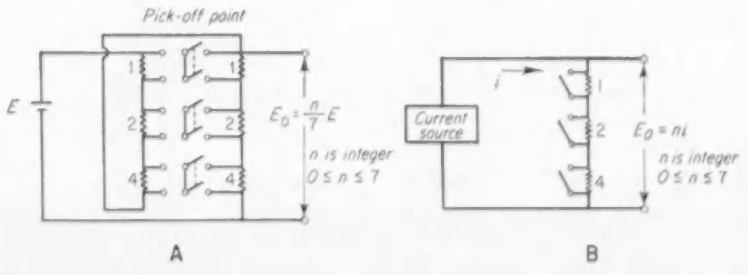


FIG. 1. Constant-voltage (A) and constant-current relay-operated voltage dividers.

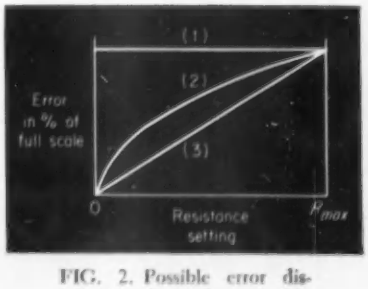


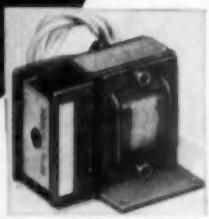
FIG. 2. Possible error distributions in a resistance stick.



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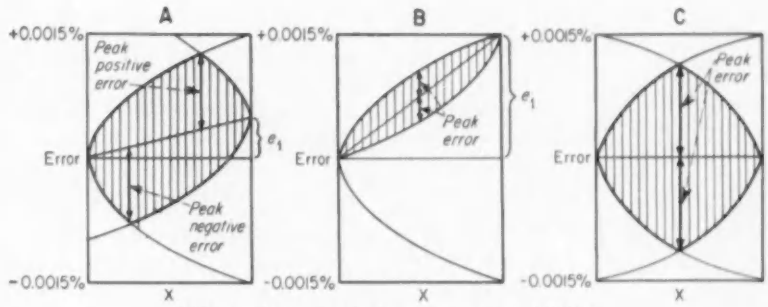


FIG. 3. Error distributions in practical ROVD's.

$$\frac{E_o}{E} \cong x + x f_e(1-x) + (1-x)[f_e(x) + kx] \quad (2)$$

where k represents the resistance mismatch between sets.

For the 17-bit set considered:

$$f_e(x)_{max} = \frac{15\sqrt{x} + 0.16}{10^6} \text{ per cent,}$$

$$k_{max} = \frac{15}{10^6} \text{ per cent}$$

The term 0.16 is negligible except within 3 per cent of zero (or 3 per cent of unity in the case of $f_e(1-x)$. The errors near zero and unity are small in any case and at peak error points the 0.16 term may be neglected.

$$\text{Error} = \frac{E_o}{E} - x = x f_e(1-x) + (1-x)$$

$$\times [f_e(x) + kx] = \frac{15}{10^6}[x\sqrt{1-x} + (1-x)$$

$$\times \sqrt{x} + x(1-x)] \text{ per cent} \quad (3)$$

The peak possible error occurs at $x = \frac{1}{2}$. Assuming that all tolerances are at their limit at $x = \frac{1}{2}$,

$$\text{Peak error} = \frac{14.4}{10^6} = 0.00144 \text{ per cent}$$

To reach this error both sticks must be at peak tolerance in opposite directions in the vicinity of $x = \frac{1}{2}$ and resistance mismatch must be at the limit. This is an unlikely combination of circumstances. The error, summed on an rms basis, is below 0.0011 per cent. To this must be added the quantizing error of 0.00038 per cent.

Type 2

Referring to Figure 3A for current source ideally calibrated, the error is zero at unity and the distribution is as shown. The error may be expressed as

$$\text{Peak error} = \text{smaller of} \begin{cases} f_e(x) - e_1 x \\ f_e(1-x) + e_1 x \end{cases} \quad (4)$$

For current incorrectly adjusted, the base line is shifted, as in Figure 5, and

$$\text{Peak error} = \text{smaller of} \begin{cases} f_e(x) - e_1 x - \Delta i x \\ f_e(1-x) + e_1 x - \Delta i x \end{cases} \quad (5)$$

For correctly adjusted current with $e_1 = 0$ (worst condition), peak possible error occurs at $x = \frac{1}{2}$

Peak error =

$$\frac{15}{10^6}\sqrt{x} = \frac{10.6}{10^6} = 0.00106 \text{ per cent}$$

For $e_1 = 1$

Peak error =

$$\frac{3.1}{10^6} = 0.00031 \text{ per cent}$$

The probable peak error is almost certainly better than 0.001 per cent even if current adjustment is not quite correct.

Shorting Resistance

This term describes the resistance remaining when a resistor is shorted out and includes lead resistance and relay contact resistance. If this amounts to a resistance r, then the net resistance change due to actuation of the relay associated with a resistor R is $|R - r|$. A representative value for r is 0.05 ohms. For 17 relays the residual resistance at $x = 0$ is 0.0005 per cent (131,071 ohms full scale). The error would be accentuated by lower full-scale resistance values. In converters of conventional accuracy (0.01 per cent) this is no problem, but the error contribution is significant in the vicinity of 0.001 per cent.

In either converter it is possible to control to within that component which is due to variable relay contact resistance. The wiring is adjusted so that all shorting resistances are equal and each resistor of the set is increased by that amount. This can be done during manufacture of the resistors or with trim wiring while they are in the circuit. Relay actuation then produces the proper change in output voltage. Such compensation cannot be used where the output voltage must pass through zero.

Transient Effects

This is an extremely important characteristic of resistors for the high-speed ROVD, since self-heating and various thermals can cause serious transient errors at tolerances below 0.01 per cent. Conventionally encapsulated resistors are particularly subject to this difficulty and should be examined for transient effects in the application. The transient specification for the previously mentioned 17-digit set is such that when switched from zero to rated current the peak effective resistance change is 0.0005 per cent.

Current Source

The chopper-stabilized dc amplifier is an appropriate current source for the type-2 converter. If offers calibration, temperature compensation, and an essentially zero output impedance for driving an appreciable load directly. An unusually good dc amplifier is required to exploit the inherent accuracy of the above-mentioned binary set. Specifically, a gain of more than 100,000 must be maintained to a high-enough frequency to allow the output to stabilize before readout, and drift must be less than 0.0005 per cent of full-scale output voltage.

Loading

Constant-voltage-driven converters are accurate only if negligible current is drawn by the load at the pick-off point. Infinite input impedance, precisely gain-controlled isolation must be provided if an appreciable load is to be driven. Alternatively, it is possible to analytically predict a load compensation using the computer facilities to obviate the problem.

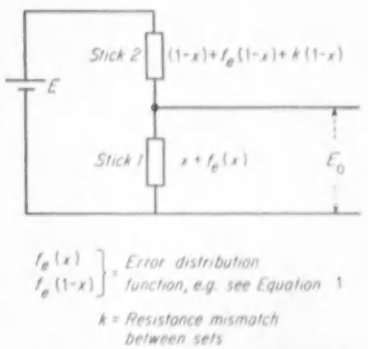


FIG. 4. Error terms in a constant-voltage ROVD.

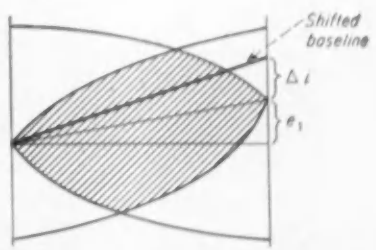
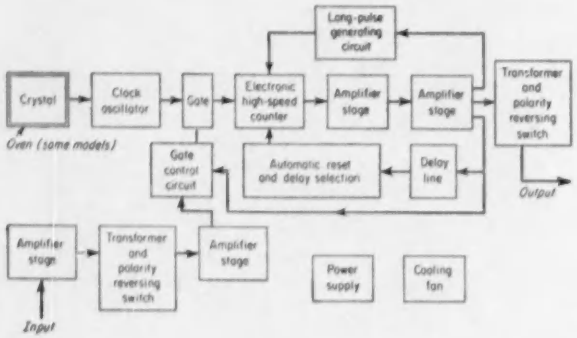


FIG. 5. Effect of a current error in a constant-current ROVD.

NEW PRODUCTS



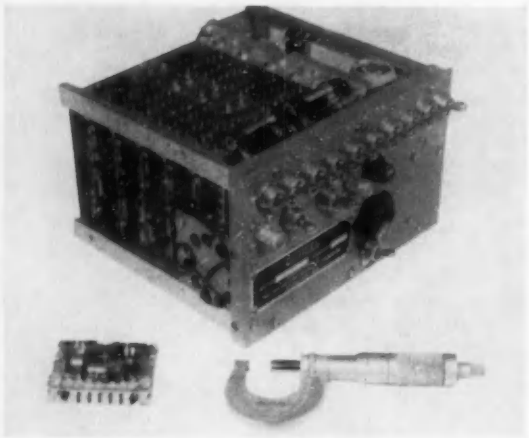
LISTING IN GROUPS

1- 5 Designs of the Month
6-17 Amplifiers, Controllers, & Analyzers
18-25 Control Components
26-36 Relays & Switches
37-50 Detectors
51-56 Power Sources
57-72 Numerical in Nature
73-77 Control Valves

DELAY LINES contain a computer's worth of components for high accuracy over long delays.

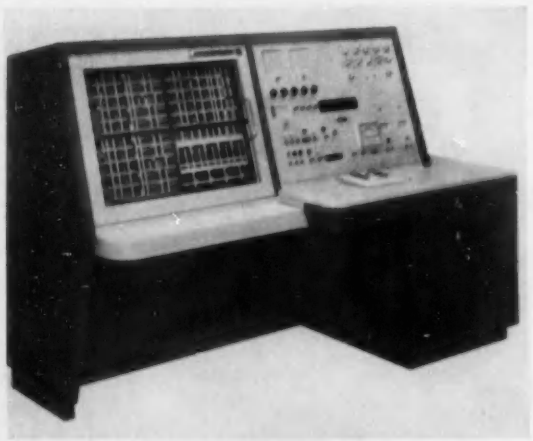
As the block diagram shown above suggests, the neat package at the right is more than just another delay line. Models are available that generate pauses of up to 2 sec with an accuracy of 2 microsec. A crystal-governed oscillator feeding a high-speed counter does it all. Because input pulses simply trigger the sequence that results in the output, low input signals will show a power gain at output.

Delays can be factory-set (in which case only enough counter circuits are included to do the job) or can be adjustable through the entire maximum range of from 4 microsec to 2.05 sec. The little machines contain their own blowers, and their innards are made of matchbook-sized plug-in circuits. The complexity of the instruments would suggest prices quite a bit higher than for conventional attentuation-type delay lines, but, says the maker, comparable accuracy over comparable ranges with precision attentuation-type delay lines (which he also makes) costs just as much.—The Jacobs Instrument Co., Bethesda 14, Md.



Circle No. **1** on reply card

ANALOG COMPUTER CONTROL CENTER aims at maximum setup simplification.



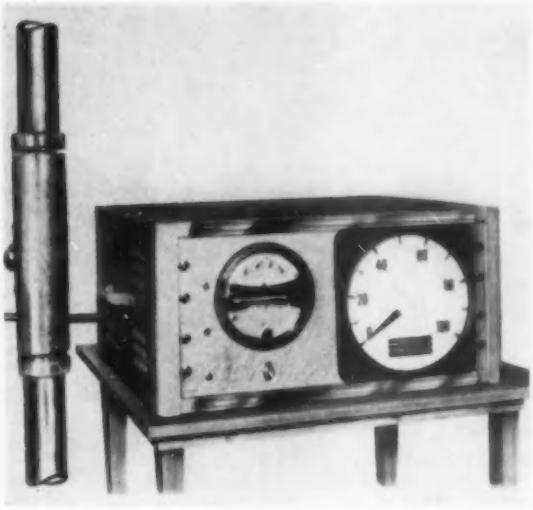
Circle No. **2** on reply card

Intended for the 200-amplifier-and-up analog computer installation, the control console here acts as a central source of program information and provides some unique functions as well. One of the most notable features is a scheme for setting pots by keyboard input. The output of the keyboard is "addressed" to the desired pot, which is then clutched into a setting servo (one used for many pots). The servo obtains its follow-up voltage not from the output of the pot, but from the output of the amplifier it is permanently connected to. In this way, low-cost pots are used and settings made which balance out errors in the amplifiers as well as pots. As result, a phenomenal 0.01 per cent accuracy is attained. Punched tapes can be prepared simultaneously, allowing automatic setup of the problem again. The whole of model 1200 EASE is loaded with simplifying features, too many to describe here.—Berkeley Div. of Beckman Instruments, Inc., 2200 Wright Ave., Richmond 3, Calif.

FLOWMETER senses through temp differential.

The flowmeter flow integrator illustrated here is said to incorporate unique principles. Here's how it works: the temperature of metered gas or fluid contained in a pipe is temperature-sensed, heated, and then temperature-sensed, in that order, in the direction of fluid flow. The faster the fluid moves, the less its temperature is raised by the heating coil, and the effect is linear. Hence, by detecting the difference in temperature of the pipe wall at the two temperature-sensing coils, a direct reading of fluid flow can be obtained and integrated (by means of a watt-hour meter) without loss of accuracy as the result of pulsations. Because there is no break in the pipe wall, the system can be used in processing foods or almost any substance without difficulty. Accuracy is better than 1 per cent.—Industrial Development Laboratories, Inc., 17 Pollock Ave., Jersey City 5, N. J.

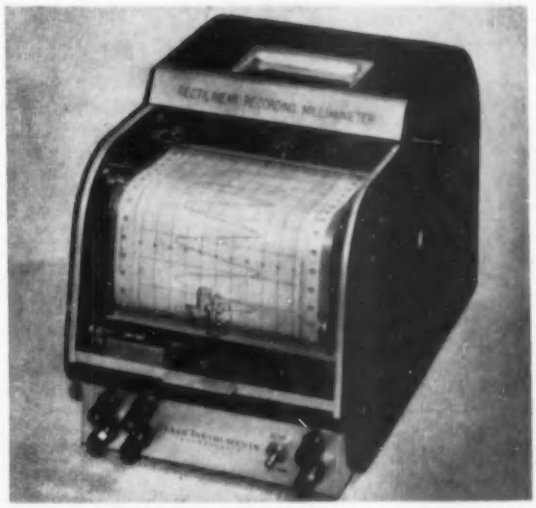
Circle No. 3 on reply card



"FIRST" rectilinear recording milliammeter.

The neat instrument shown here uses a 1-ma galvanometer movement and is said to be the first rectilinear ink recording milliammeter. Ink level is visible at all times through the plastic sliding cover. The instrument can be refilled from the front. The rectilinear pen motion is accomplished by pantographic-type linkages through a 4½-in. deflection range. A 1-ma input through 1,500 ohms provides full-scale deflection. Undamped natural frequency is 2 cps. Either ac, dc, or spring drives are available in 10 ranges, so that the 100-ft-long graph paper can be run through in an hour and 40 min or up to 60 days. Six in. of paper are available for observation at one time.—Texas Instruments Corp., 6000 Lemmon Ave., Dallas 9, Tex.

Circle No. 4 on reply card



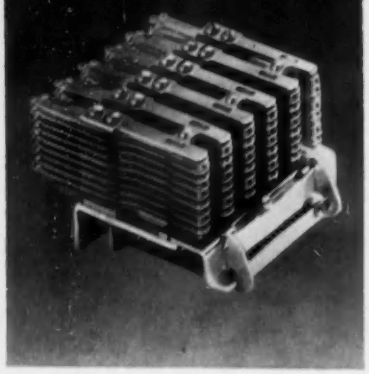
STORAGE SYSTEM for compacting heavy data.

It's said that this machine will compact the contents of 1,600 conventional file cabinet drawers into a space less than 3 cu ft. In addition to processing data for use by digital computers, the apparatus can perform many routine accounting functions, such as collation, selection, sequencing, or separation of inventory, billing, or other routine data. Input to the Underwood ELECOM File Processor is a punched-tape reader or typewriter keyboard. The keyboard operator selects the type of operation, which then becomes automatic except for changes of tape reels. As many as 30 items can be processed in 1 sec. The machine will be sold for approximately $125,000. When used with Underwood's ELECOM computer, the faster machine handles the complex operations, and the File Processor the bulk of the data.—Underwood Corp., One Park Ave., New York 16, N. Y.

Circle No. 5 on reply card



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TYPE "B" RELAY

If reliable operation of a large number of contacts has application to your work, you should examine this remarkable relay, manufactured with extreme precision.

Our gang-type "B" relay can be furnished with combinations of A, B or C contacts with a capacity of up to 60 form A contacts. It will accommodate six stacks of spring combinations which, due to special construction, occupy an unusually small space and make the relay desirable for group mounting.

This relay has been for years distributed exclusively and in large numbers to the Independent telephone industry. Expanded production facilities enable us now to offer it to the general engineering world. Like all our relays, it is designed to operate under extreme ranges of temperature and humidity.

On request . . . If you will write or call, and state the application you'd plan to use it in, we'll be happy to send additional information, and a catalog of our entire relay line. No obligation, of course.

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NEW PRODUCTS

AMPLIFIERS, CONTROLLERS & ANALYZERS



SERVO-AMPLIFIER LINE: Available in **ratings of from 2 to 10 watts** is a new line of 400-cycle electronic servo amplifiers that complements its maker's 400-cps power supplies and modulators. – Eastern Components Div. of Servomechanisms, Inc., 625 Main St., Westbury, N. Y.

Circle No. 6 on reply card

COMPUTER NOISE GENERATOR: A new low-frequency noise generator is marketed for analog computer use. Output is a waveform of constant amplitude with variable width. **The noise source consists of a radioactive sample** and a Geiger tube actuating a flip-flop to generate square waves. The mean value of the output is within 1 per cent of the full scale mean, and **the spectrum uniform is within 3 db from dc to 300 cps.**–J. B. Rea Co., 1723 Cloverfield Blvd., Santa Monica, Calif.

Circle No. 7 on reply card

TRANSISTOR SERVO AMPLIFIERS: A recent offering of transistor servo amplifiers and companion size-8 servo motor and motor generator is said to perform beyond items heretofore available. The servo motor (¾ in. max OD) delivers a stalled torque of 0.2 oz-in. when at normal operating temperature. The servo amplifiers (three of them) **have input impedances of 10 k ohms, and gains of 3,500,** and cases about the size of a cigarette package. Outputs will **provide the size-8 motors with as much as 0.17 oz-in. torque.**–Transicoil Corp., Worchester, Pa.

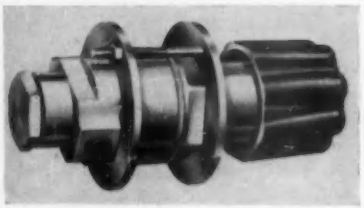
Circle No. 8 on reply card

PHASE SHIFTER: Shifts from 90 deg lagging to 90 deg leading of 450 volt-ampere, three-phase delta inputs are achieved by a vacuum-sweeper-sized device. The mechanical rotation of a **transformer-like winding does the shifting,** with scale indication in degree and power factor.–Knopp, Inc., 4289 Holden St., Oakland 8, Calif.

Circle No. 9 on reply card

ANALOG COMPUTER FEATURE: An addition available for all "400" series REACs is a "Time Scale Check" which, **at the flip of a switch, runs the problem at half speed.** A check of corresponding points immediately determines whether the original speed introduced errors due to component frequency limitation.–Reeves Instrument Corp., 215 E. 91st St., New York City.

Circle No. 10 on reply card



HIGH-PRESSURE REGULATOR: APCO's new manually operated high-pressure regulator takes up to 4,500 psi and is said to contain a host of unusual features–Accessory Products Corp., 616 W. Whittier Blvd., Whittier, Calif.

Circle No. 11 on reply card

REDESIGNED SERVOSCOPE: A multiple-signal generator and phase-angle detector for the analysis of system dynamic performance now **has had its face redesigned according to human engineering principles.**–Servo Corp. of America, 20-20 Jericho Tnpke., New Hyde Park, N. Y.

Circle No. 12 on reply card

PHASE-SENSITIVE AMPLIFIER: A new amplifier for infrared detection apparatus **has bandwidth restricted to about 20 cycles at 450 cps,** with discrimination against random phase signals in that range. A bias source for photocells is built in, with a microammeter for the indication of bias current.–Baird Associates, Inc., 33 University Rd., Cambridge 38, Mass.

Circle No. 13 on reply card

Doelcam

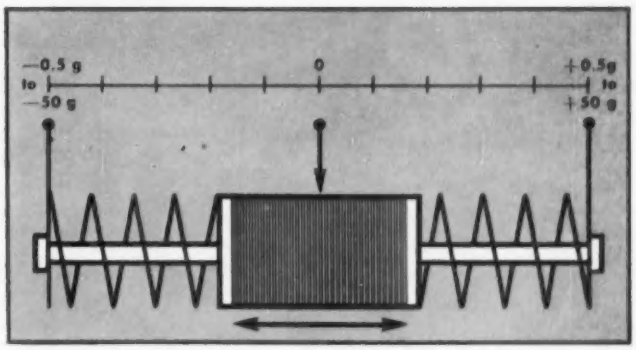
LINEAR ACCELEROMETERS
for Aircraft and Missiles

ZERO CROSS-COUPLING NON-PENDULOUS TYPE



Shown Actual Size

Doelcam Linear Accelerometers sense positive or negative accelerations or both in either the vertical or horizontal plane. Designed for use in aircraft and missiles, they are available in a variation of ranges from ± 0.5 g to more than ± 50 g's depending upon requirements. These units consist of a centrally located mass restrained by coil springs and supported on a linear-type ball-bearing. Any movement of the mass on either side of the null displacement position is measured by a potentiometer pick-off, providing a high level output signal. Viscous damping is incorporated for improved dynamic response. Zero cross-coupling is inherent with this true linear non-pendulous design. (Cross-coupling is defined as a change in output signal caused by an acceleration applied from any direction in a plane normal to the sensing axis) Excitation may be as high as 100 volts (A-C or D-C) depending on the potentiometer resistance.



- LINEAR RESPONSE
- D-C OUTPUT SIGNAL
- VISCOUS DAMPING
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- EXTREMELY RUGGED
- WEIGHT: APPROXIMATELY 0.9 POUNDS
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sensitive compact rugged



IR-226 ACTUAL SIZE
- **Rotary Armature**
- **SPDT at 20 MW**
- **DPDT at 40 MW coil input**
- Many variations available

The IR-226 sealed sensitive relay was created by North to fill many of the most critical needs for airborne system switching. This includes full compliance with Mil specs. It does many jobs better than anything else devised for the purpose, according to reports from important prime contractors. Their testimony is backed by rapidly mounting repeat orders. Our field engineer in your area can quickly provide detailed application data on IR-226 and many other promptly delivered

NORTH RELAYS

NORTH ELECTRIC COMPANY
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NEW PRODUCTS

CONDUCTIVITY CONTROLLER: An adaptation of its Series 97 temperature controller has been designed by Fielden specifically for conductivity control. A single set-point knob on the front provides two-zone action for both alarm and control. Automatic temperature compensation for conductivity variations limits the **maximum error to plus or minus 2 per cent.** It's available with a variety of conductivity cells, and includes fail-safe operation.—Fielden Instrument Div. of Robertshaw-Fulton Controls Co., 2920 N. Fourth St., Philadelphia 33, Pa.

Circle No. 14 on reply card



OSCILLATOR: Sinusoids ranging from **1 cps to 1 mc** are put out by a new oscillator with less than 0.1 per cent distortion for any frequency or amplitude. Output impedance of 600 ohms, and the 0-to-8-volt rms signal contains no dc. The maker claims a radically new frequency generator circuit using only two vacuum tubes.—Donner Scientific Co., 2829 Seventh St., Berkeley 10, Calif.

Circle No. 15 on reply card

POCKET TRANSISTOR TESTER: A fist-sized transistor tester, now available, will indicate shorts, opens, leakage and current gain. Included with the tester are five universal transistors and an interchangeability chart. The list is $39.95.—General Electric, Electronics Park, Syracuse, N. Y.

Circle No. 16 on reply card

LIQUID-LEVEL PROBES: A line of liquid-level probes for use in the process industries is **offered in a variety of rugged metals** with enclosures for outdoor applications. — Machinery Electrification, Inc., Northboro, Mass.

Circle No. 17 on reply card

How to Control a Home Air Conditioner

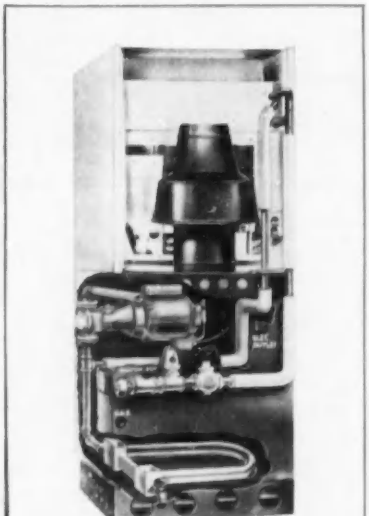
No. 2 of a series — *Showing the broad application range of Fenwal Controls*

In this packaged high efficiency home heating and cooling system, a gas boiler and a water chiller combine to raise or lower the temperature of water circulating to the room conditioner units. The problem was to regulate the temperature of the water precisely, by supplying or removing just enough heat, so that the desired room temperature would be assured.

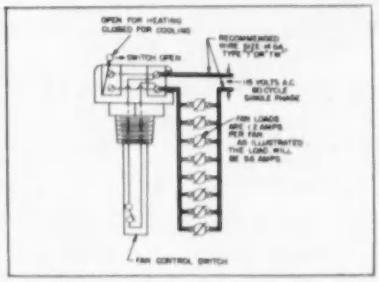
The solution was a Fenwal Snap-Action THERMOSWITCH control, Series 20000. Temperature range of this particular model is 25° to 225°, and the setting is at 100° ± 3°F. The device functions as a low limit common fan control for all unit room conditioners. In the heating operation it permits fans to operate when the boiler water temperature reaches 100°F, shuts them off when water temperature drops below 100°F. In the cooling operation the cover-mounted toggle switch permits continuous fan operation and acts as an off-on switch for all room unit fans.



A FENWAL SNAP-ACTION THERMOSWITCH® UNIT in this home air conditioner effectively controls both heating and cooling operations. This type of Fenwal device is ideal where a local bulb unit is required for accurate control with relatively large electrical loads.



LOCATION of the Snap-Action THERMOSWITCH control in the air conditioner is at the boiler outlet, between the outlet and the pressure relief valve at the system supply outlet. This cut-away view shows its position relative to other elements in the system's central unit.



FANS ARE CONTROLLED by the Snap-Action THERMOSWITCH unit as shown in this wiring diagram. Note the toggle switch (top), manually operated for heating or cooling, the thermostatically operated fan control switch (bottom), and the individual fan connections (right).

OPERATING PRINCIPLE. In the Fenwal Snap-Action THERMOSWITCH control, Series 20000 and 21000, contacts in the head are actuated by a push-rod connected to a bellows in the liquid-filled shell. High thermal activity, necessary to combine close control with "snap" contact actuation, is achieved by converting the cubical expansion of the liquid to linear motion of the push-rod at the snap switch. Since the liquid completely surrounds the bellows and is in direct contact with the external shell, fast response is assured. Units are available in six standard temperature ranges between −75°F and +300°F. Units are UL approved.

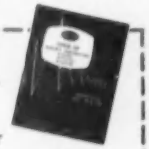


Many Other Uses

Among the growing list of applications for Fenwal Snap-Action THERMOSWITCH controls are: hot drink vending machines, commercial laundry equipment, commercial dishwashers and swimming pool heaters. Wherever accurate, sensitive temperature control under high electrical loads is required, the Series 20000 and 21000 units offer advantages found in no other thermostatic controls.

For Your Own Applications

Investigate the many different types of Fenwal temperature control and detection devices. Besides the 20000 Series described here, these include standard THERMOSWITCH units, Midgets, Miniatures, Indicating Controllers, etc. Send the coupon for new Catalog No. 500 and remember that Fenwal's engineering staff is always ready to help you solve any temperature control problem.



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Ashland, Mass.

Please send me your Catalog No. 500. Our specific problem is:.....

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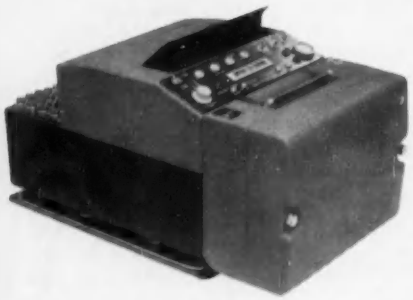
Fenwal CONTROLS TEMPERATURES . . . *PRECISELY*

vital tests?

lots of data?

Here's the acknowledged peak of recording oscillograph development – CEC's Type 5-119, usable for over 90% of all static-dynamic tests, regardless of their complexity. An unusual group of *built-in* safeguards against data loss has proved especially valuable in aircraft flight testing and in missile testing, where conditions are often impossible to duplicate and lost data can mean tens of thousands of dollars. In the air or on the ground, you can be *sure* when you use the CEC 5-119.

then try CEC's 5-119 recording oscillograph





Also, the 5-119R, especially engineered for vertical installation. Effectively shock mounted, using little space, it's ideal for both stationary and mobile rack mounting... tilts forward easily for loading and adjustment.

The 5-119 records up to 50 channels on records 12"x250 ft at speeds from 0.1 to 100 inches per second. *Instant* speed change of 10:1 is effected through a simple switch control. It uses standard CEC Galvanometers, with linear frequency response from 0 to 3000 cps. All controls and warning lamps are located on the front panel.

For complete information about the 5-119 oscillograph, write today for CEC 1536B-X5.

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NEW PRODUCTS

CONTROL COMPONENTS

HOSE FITTINGS: A new push-on low-pressure fitting and a two-bolt clamp fitting for high-pressure applications come in sizes of from ¼ through ½ in.–Flex-O-Tube Div. of Meridan Corp., 2525 Jim Daly Rd., Inkster, Mich.

Circle No. 18 on reply card

3-IN. CRT CAMERA: Said to be the first camera specifically designed for use with 3-in. cathode-ray tubes, a new device recently marketed offers full binocular vision and **produces a print 2 min after exposure.** The lens will enable writing speeds of up to 1 in. per microsecond with type-31 film.–Allen B. DuMont Laboratories, Inc., 750 Bloomfield Ave., Clifton, N. J.

Circle No. 19 on reply card



MINIATURIZED CONNECTORS: The little connectors shown in the right-hand side of the photo are said to **offer greater reliability** as well as reduced size. They are available in 14,- 24,- and 36-contact sizes.–American Phenolic Corp., Chicago 50, Ill.

Circle No. 20 on reply card

PRINTED-CIRCUIT TUBE SOCKETS: A unique design for a tube socket places it at right angles to a printed-circuit board, allowing dip soldering attachment of the socket but normal freedom for the tube.–Aerovox Corp., New Bedford, Mass.

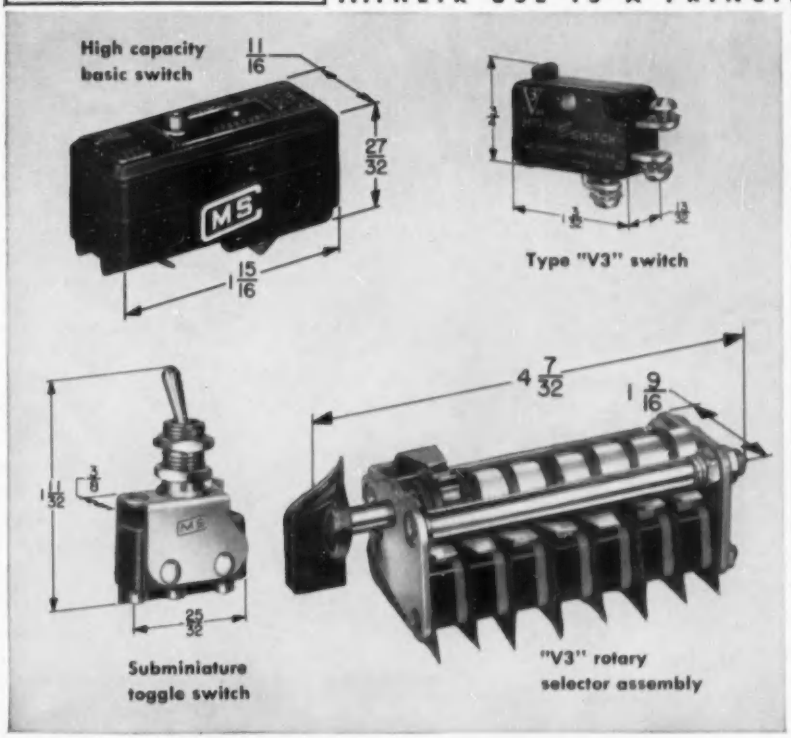
Circle No. 21 on reply card

VIBRATORY FEEDERS: A new line of vibratory feeds claims less power consumption and simpler construction. These vibrators work from 60-cycle current without rectifiers and are **for direct attachment to bins, ducts, etc.** –Eriez Mfg. Co., Erie 6, Penn.

Circle No. 22 on reply card

MICRO *precision switches*

...THEIR USE IS A PRINCIPLE OF GOOD DESIGN



A continuous flow of Precision Switch developments anticipates designer's needs

Whatever the design requirement—whether it calls for unusually small size, unusually high electrical capacity or unusual actuation and circuit arrangement—there is a MICRO precision switch to meet it. That is why designers have long made it standard policy to check with MICRO SWITCH as new needs develop.

Shown here are just a few small, compact switch designs that are typical of MICRO SWITCH development. Each is one of a whole "family" of extremely reliable switches.

Type "V3" Switch. The MICRO SWITCH "V3" line switches have the highest electrical capacity for their size of any switch available. They have been developed to meet the exacting requirements of designers for an extremely small, compact switch without sacrifice of quality. Actuators are available to permit their actuation by cams, slides and other mechanical motion not in line with the switch plunger motion. (Send for catalog 74).

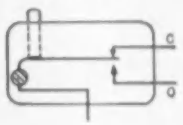
"V3" Rotary Selector Assembly. These assemblies are available with from one to eight switching units and from two to eight detent positions. Light in weight and small in size, these assemblies are well suited for use in electronic and aircraft applications. Many assemblies are available with various camming sequences. (Send for catalog 74).

High Capacity Basic Switch. This switch combines high electrical rating with high inrush capacity. The steady state current rating is 20 amperes, with inrush capacity of 75 amperes on voltages up to 460 volts a-c. These switches are especially useful for handling high inrush currents of solenoids, motors and tungsten lamps. (Send for catalog 62).

Subminiature Toggle Switch. This is one of a number of subminiature toggle switch designs developed for subminiature assemblies. The toggle switch illustrated consists of one MICRO subminiature switch riveted into the stainless steel toggle bracket. The assembly is for single-pole, double-throw service. Double-throw switches can be used "normally open" or "normally closed" by wiring to either the normally open or normally closed terminals. (Send for catalog 75).

Circuit Arrangements

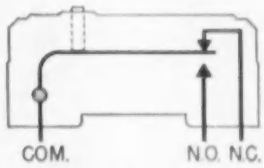
DOUBLE THROW



Type V3 Switch

This switch has a single-pole, double-throw contact arrangement. Electrical rating is: 10 amperes, 125 or 250 volts a-c; ½ ampere, 125 volts d-c; ¼ ampere, 250 volts d-c.

DOUBLE THROW

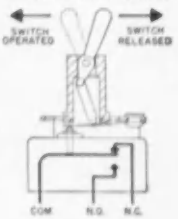


High Capacity Basic Switch

Standard switches are single-pole, double-throw. Electrical rating is: 20 amperes 125, 250 or 460 volts a-c; ½ ampere 125 volts d-c; ¼ ampere 250 volts d-c; 1 H. P. 115 volts a-c; 2 H. P. 230 volts a-c; 10 amperes 125 volts when controlling tungsten filament lamp loads on a-c circuits.

Subminiature Toggle Switch

Contact arrangement is single-pole, double-throw. Double-pole, double-throw assembly, using two subminiature switches is available. Electrical rating is: 5 amperes 125 or 250 volts a-c. The 30 volt d-c rating is, inductive—3 amperes at sea level and 2.5 amperes at 50,000 feet, resistive—4 amperes at sea level and 4 amperes at 50,000 feet, maximum inrush is 15 amperes.



MICRO SWITCH Engineering Service, experienced in precision switching problems, is available—at the MICRO SWITCH branch nearest you. Why not call today?

MICRO SWITCH

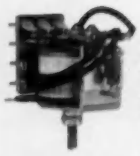
A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

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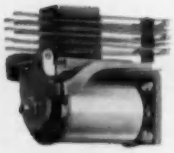


Shop-talk among engineers in various industries is spreading the good news about the *Phillips Plan*—a special combination of engineering skill* and personal service. To put the skids under a sluggish relay problem, contact Phillips. Write us, or call your local Phillips man for prompt consultation.

* **FOR EXAMPLE:**
Phillips Engineered Relays **meet the highly critical requirements of radar tracking equipment.**



TYPE 13 QA/TYPE 13AC — Power relay, five pole, single stud mounting. O.D. 1-3/8" W x 1-3/16" H x 15/16" W. AC and DC.



TYPE 3QA — Multi-contact relay, using short coil for economy in size and weight. O.D. 1-1/4" W x 2-1/2" L.



40006 TYPE 4 — Enclosed relay. Octal plug. O.D. 1-5/8" diameter x 2-19/64" H.

MULTI-CONTACT, POWER, HERMETICALLY SEALED RELAYS - ACTUATORS

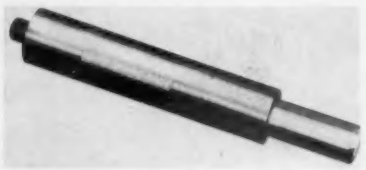
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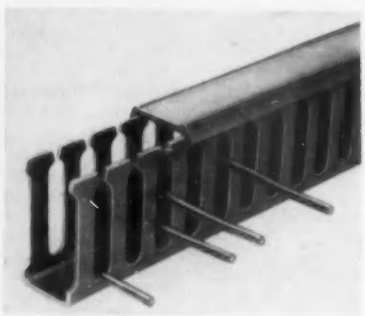


SUPER SPRING: The compressibility of fluids is used as the source of spring action in a line of **combination shock-absorbers and springs** with forces substantially greater than anything using conventional metal coils.—Taylor Devices, Inc., 188 Main St., North Tonawanda, N. Y.

Circle No. 23 on reply card

POTTING KIT: Intended for use by electronics engineers interested in exploring the feasibility of potting circuits, a kit is now available with elements setting at room temperature, flexible molding material, dip insulating plastic, and heat cured material.—Plastronics, P. O. Box 96, Winter Hill 45, Mass.

Circle No. 24 on reply card

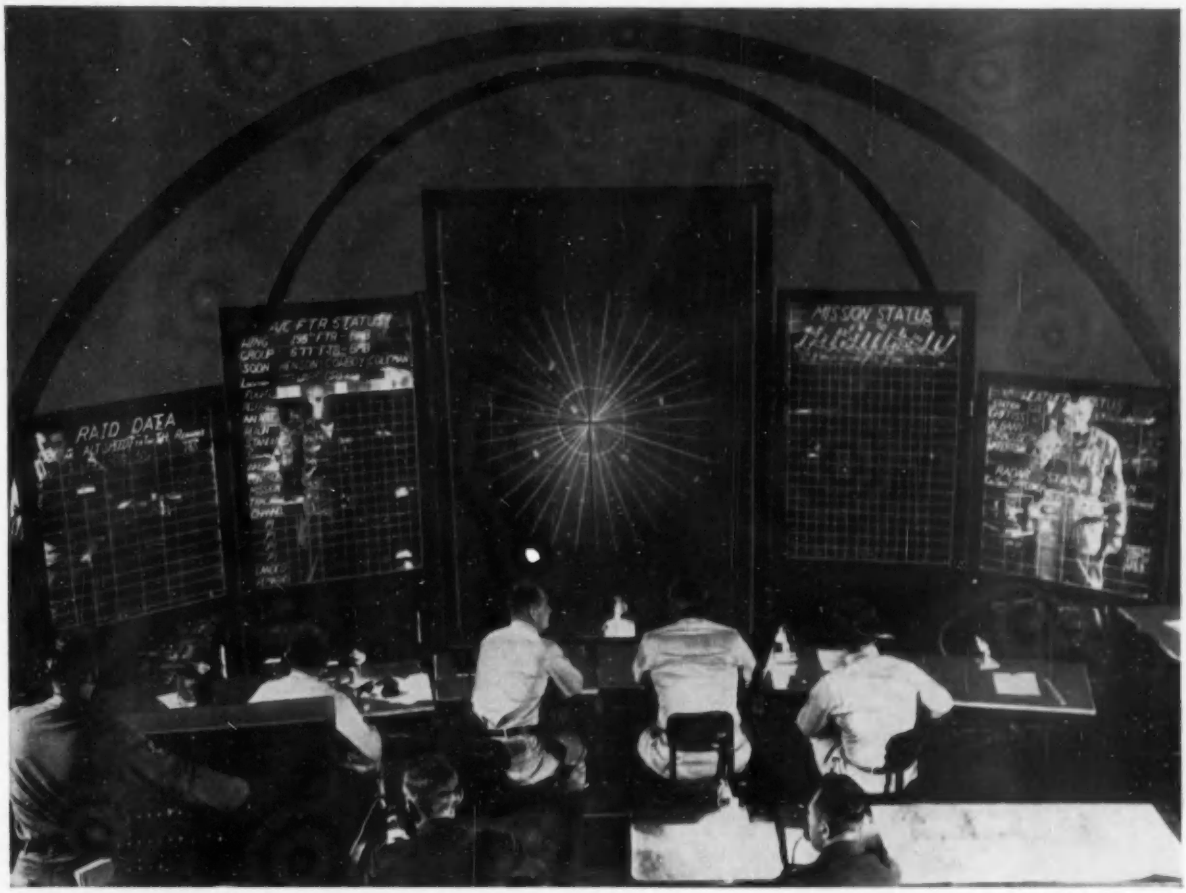


PLASTIC WIRING DUCT: The light-weight wiring duct seen here comes in sizes ranging from 1 by 1 in. by 5 ft to 3 by 3 in. by 5 ft. The maker claims it won't warp.—Panduit Co., Dept. CLN, 10132 S. Washtenaw Ave., Chicago 43, Ill.

Circle No. 25 on reply card

RELAYS & SWITCHES

SHORT PHONE RELAY: Designed for crowded circuits, a sealed, short-form telephone relay can be supplied with copper slugs for time delay, special contact materials, and **coils up to 38,000 ohms, single- or double-wound.** The series SE relay comes with a



Official U.S. Air Force Photograph

Friend or foe? Tactical defense officers in MINK control center watch movements of aircraft as reported from radar warning sites. This is equipment developed under the direction of Rome Air Development Center.

ROME AIR DEVELOPMENT CENTER PROVIDES AIR DEFENSE EQUIPMENT FOR OUR AIR FORCE

One development agency for the Air Force's ground-based electronic equipment is Rome Air Development Center, located at Griffiss AFB in Rome, N. Y. One of the ten centers of the Air Research and Development Command, RADC is concerned with the air defense of our nation, with providing equipment for tactical supremacy, and with developing ground complexes for various navigation systems to aid all aircraft. In addition, RADC is charged with data handling improvements for the Air Force intelligence mission.

RADC is the responsible center for development, through its various contractors, of such end products as radar sites, including improved tubes, circuits, antennae, and shelters; ground communications equipment and associated support items; IFF (Identification Friend or Foe) environments, and electronic countermeasures.

Bringing complex systems from the written requirements to the actual hardware items to be used in the various Air Force commands is a long and tedious business which draws upon the skills of RADC's 500 civilian and military engineers and their many counterparts in private industry.

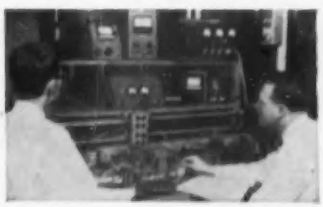
84

FORD INSTRUMENT COMPANY

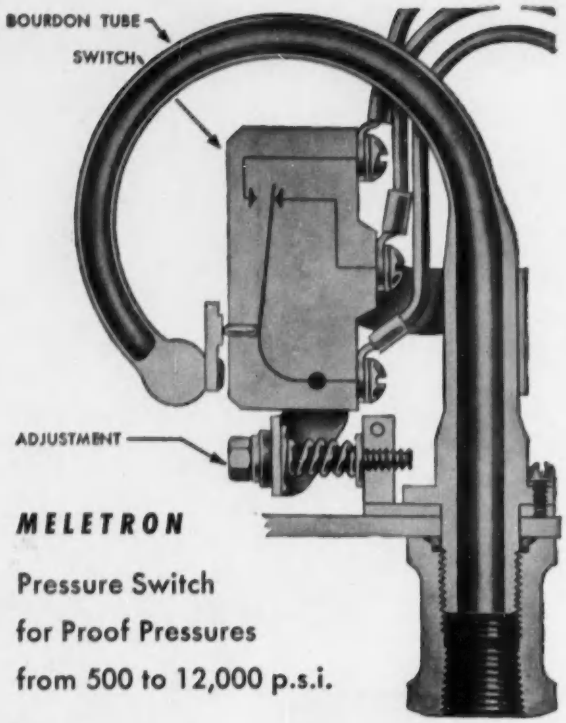
DIVISION OF SPERRY RAND CORPORATION

31-10 Thomson Ave., Long Island City 1, N. Y.

This is one of a series of ads on the technical activities of the Department of Defense.



Engineers at Ford Instrument Company working on a special Air Force project in one of the company's laboratories.



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for Proof Pressures
from 500 to 12,000 p.s.i.

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Note, that we don't use

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which, as they wear, cause settings to drift.

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on moving equipment, even under vibration, switch performs with equal efficiency.

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which require that the pressure switch be mounted absolutely vertical, which make it very critical to vibration.

To get complete operating characteristics and specifications ask for bulletins 302 to 382.

BARKSDALE VALVES

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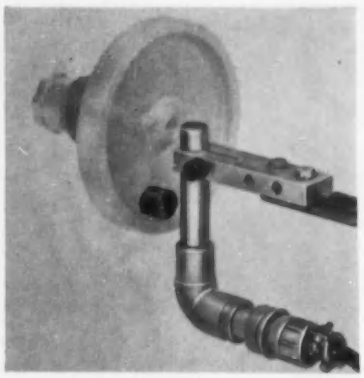
NEW PRODUCTS

maximum of ten form A or six form C Contacts.–Kurman Electric Co., Inc., 35-18 37th St., Long Island City, N. Y.

Circle No. 26 on reply card

TIMER KIT: A new kit for the experimenter offers a quick and simple way of arranging prototype timers. Up to 12 cams may be used, with 96 time cycle possibilities. The kit includes a variety of motors, gears, switches, hardware, and even tools, all housed in a wooden box.–Industrial Timer Corp., 1407 McCarter Highway, Newark, N. J.

Circle No. 27 on reply card



MAGNETICALLY TRIPPED SWITCH: A little switch inside the clamped tube shown in the photo closes in the proximity of magnetic fields as fleetingly as 8 millisec. It will follow speeds of up to 200 cps for over **30 million cycles** with the spdt **contacts carrying up to 5 amps.**–Post Machinery Co., Beverly, Mass.

Circle No. 28 on reply card

ACCURATE DELAY RELAYS: Two new relays are said to be **within ½ of 1 per cent accurate** of full scale (30 sec and up), and to within ½ of 1 per cent on faster ranges. Contact ratings are 15 amps. Type 412 resets upon power failure, while Type 422 merely suspends action until power is restored.–The R. W. Cramer Co., Inc., Centerbrook, Conn.

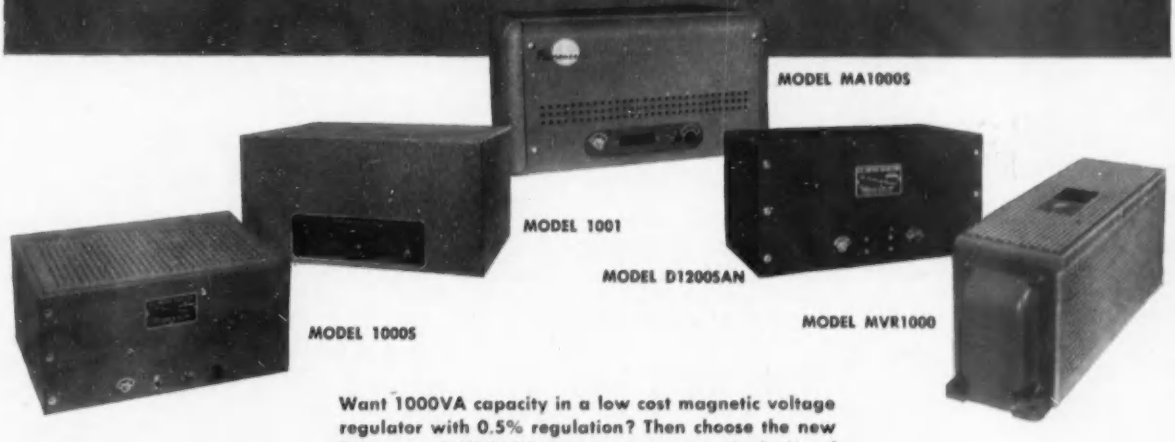
Circle No. 29 on reply card

WATERTIGHT TRANSPARENT SWITCH: The makers of a line of limit switches claim that their new models (plastic covered so you can

SORENSEN

ENGINEERS *STANDARD* MODELS TO MEET *SPECIAL* REQUIREMENTS

to illustrate this flexibility, engineers can now choose from five 1000VA regulators!



MODEL 1000S — Automatic wide-range electronic regulation with the original Sorensen frequency insensitive circuit incorporating the safety diode. Regulation ±0.1%.

MODEL MA1000S — For unattended installations requiring extremely dependable automatic line regulation. This tubeless unit offers stable long-life performance with minimum maintenance. Regulation ±0.5% over wide frequency range.

Want 1000VA capacity in a low cost magnetic voltage regulator with 0.5% regulation? Then choose the new Sorensen MVR1000; compact, economical. Need 1000VA, but with *0.01*% regulation? Then choose Model 1001. For *any* requirement, *any* application, there's a Sorensen 1000VA unit engineered with you in mind.

And the same thing is true for practically *any* specified requirement in the field of regulated power — whatever you need, Sorensen makes it now or will make it to do exactly the job you want done, within the limits of your particular application. Sorensen offers you the widest possible range of characteristics. For research or industry, call on Sorensen — *the world's authority on regulated power.*

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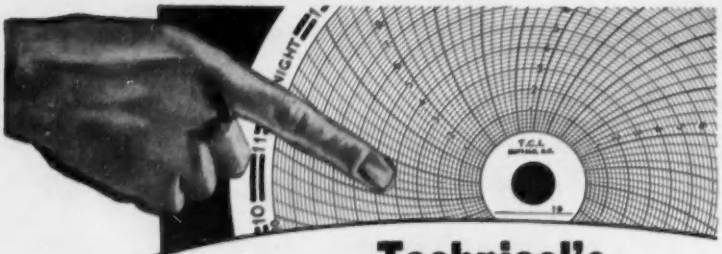
MODEL 1001 — Developed from unique, dependable Sorensen regulating circuit, refined for ultra-precise ±0.01% regulation.

MODEL D1200SAN — ±0.25% regulation for 400 cycle industrial and aircraft requirements up to 1200VA.

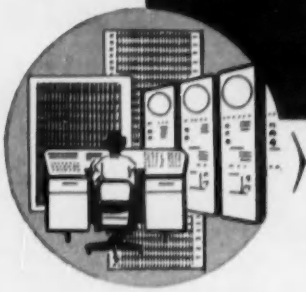
MODEL MVR1000 — New low cost compact magnetic voltage regulator for less exacting applications. Fully automatic ±0.5% regulation with fast response time.

Sorensen

SORENSEN & COMPANY, 375 FAIRFIELD AVENUE, STAMFORD, CONN.

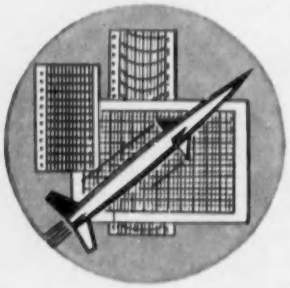


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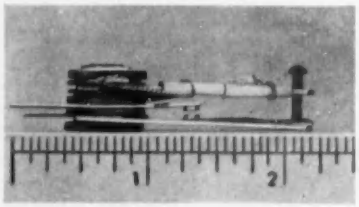
see the contacts) are the first on the market to be fully watertight. **Nineteen contact arrangements are stocked.** –R. B. Denison Mfg. Co., 102 St. Clari Ave., N. W., Cleveland 13, Ohio.

Circle No. 30 on reply card



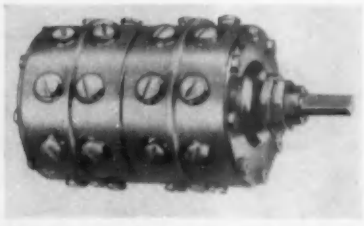
RESETTING SWITCH: Small though it may be, this little switch contains a solenoid that operates the detent holding the toggle lever in the "on" position. Hence, **power interruption causes the handle to snap to "off".** Manual operation to "off" is also possible, even though power is on. It will handle a 2-amp inductive load for 25,000 cycles.–Eclipse-Pioneer Div. of Bendix Aviation Corp., Teterboro, N. J.

Circle No. 31 on reply card

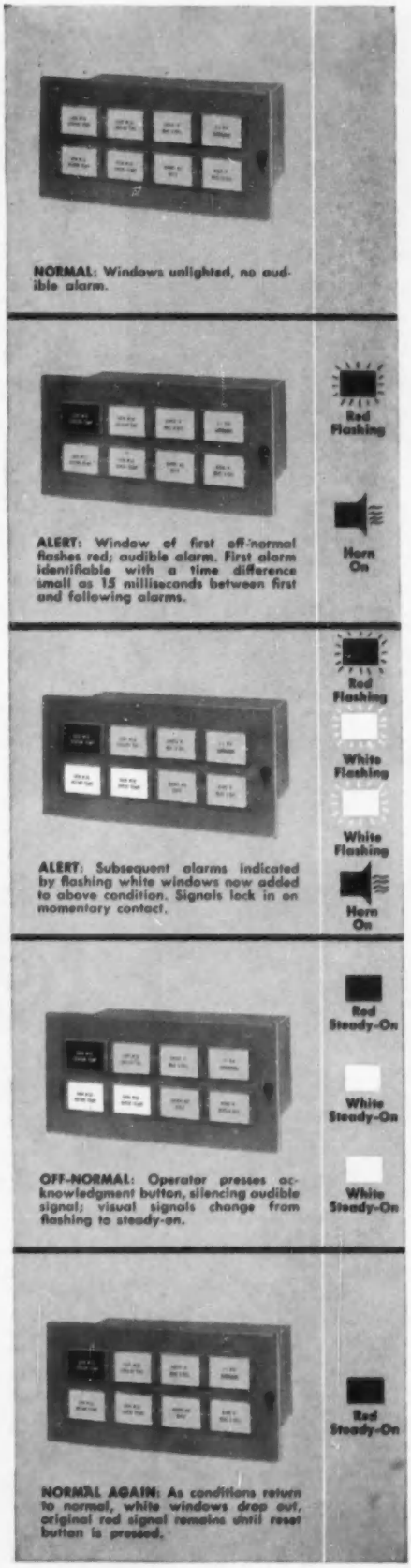


TIME-DELAY RELAY: The TR-30 thermal time delay relay **handles up to 30 amp with delays up to 3 min,** factory adjusted to within 10 per cent. It can be supplied hermetically sealed with spst or spdt contacts. Operating voltages range up to 220 ac.–Precision Magnetic Devices, Inc., P. O. Box 312, Hackettstown, N. J.

Circle No. 32 on reply card



60-AMP ROTARY SWITCH: As many as three sections can be added to this rugged rotary switch, providing up to 24 separate circuits. It's



Panalarm "VS" Annunciator identifies first off-normal from subsequent alarms for rapid corrective action

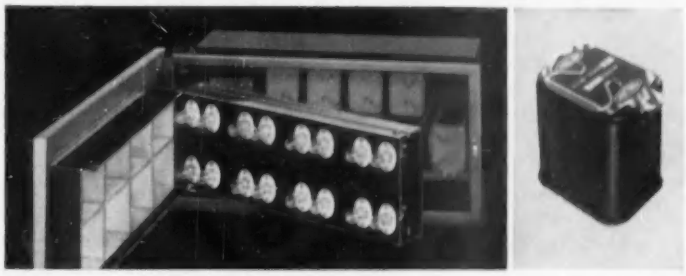
You gain the control advantages of an audio-visual information system, not just an alarm system, with the Panalarm "50VS" Visual Sequence Annunciator. This is particularly valuable when one off-normal condition will cause a "chain-reaction" of off-normals. Typical Panalarm applications are found in the process industries and among users of automatic machinery.

The original off-normal is clearly identified, enabling the operator to take immediate, corrective action. A considerable saving in down-time can often be effected simply by knowing the original source of trouble.

Panalarm "50VS" is completely flexible in setting up various sequential groups. Any number or combination of signals may be grouped as an independent sequence, and the groupings may be changed at any time by simple jumpers on the terminal block. Signals may be either illuminated nameplate or bullseye indicators, combined with a horn, bell or other audible signal. Signaling is simple and positive. A typical sequence is illustrated on the left.

Write for literature on the "50VS" and other Panalarm Annunciator Systems. A Panellit sales engineer will be happy to make a survey of your production operation to determine whether a Panalarm system can help increase efficiency and safety in your plant.

All Panalarm Annunciator Systems are completely modular, permitting future growth and changes. The photographs below illustrate a typical Panalarm Cabinet with illuminated nameplates and the hermetically sealed Panalarm "50" plug-in relay unit. Components throughout are ruggedly built to instrument standards for continuous, dependable duty. Entire Panalarm system is suitable for Class 1, Division 2 installations.



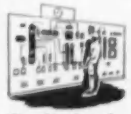
Listed by Underwriters' Laboratories

U.S. Patent No. Re-24,031

Engineered Information Systems for Industry



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PANALARM

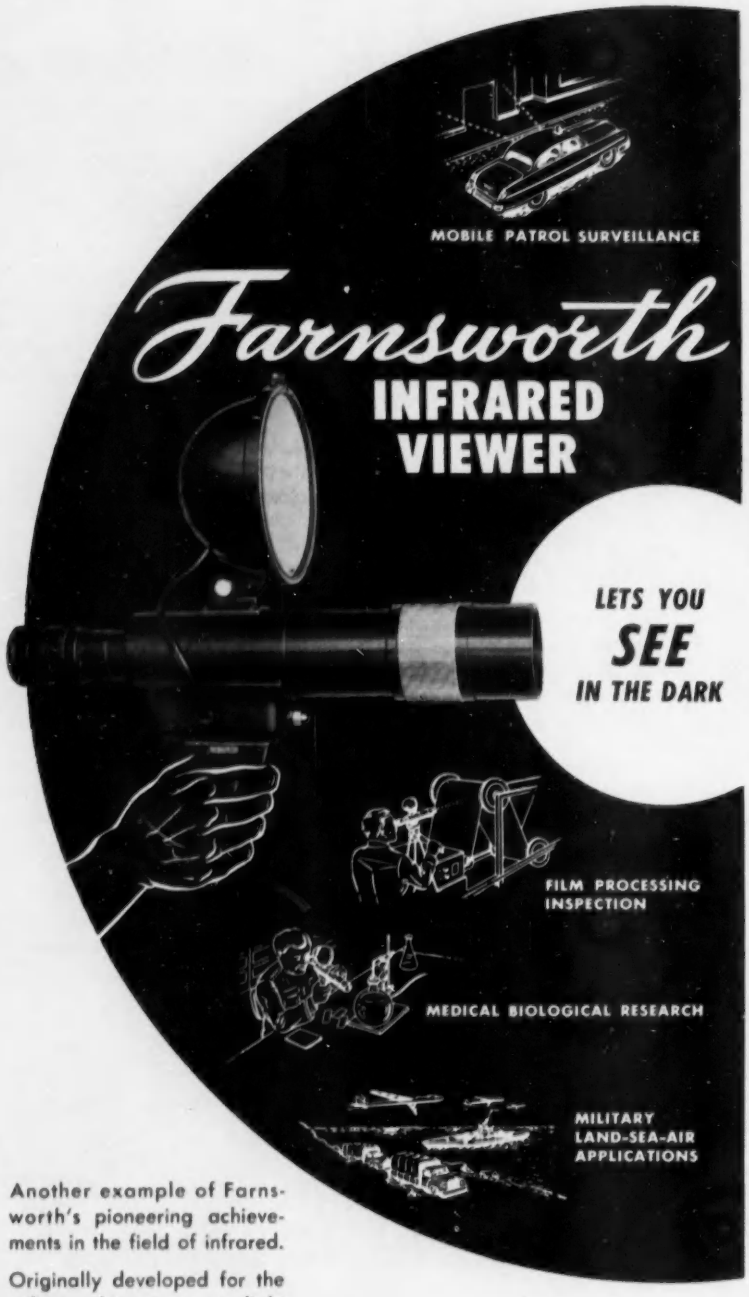
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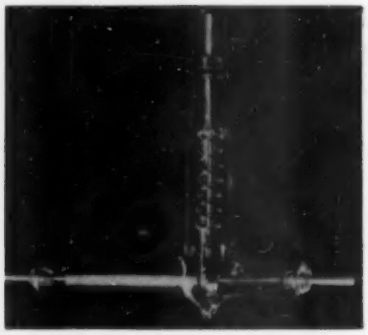
rated for 60 amps continuous, and at **35 amps inductive at 28 vdc and 50,000 feet.**–Mason Electric Corp., 3839 Verdugo Rd., Los Angeles, Calif.

Circle No. 33 on reply card



SHORTING SWITCH: Designed for shorting action, this switch can be furnished with enough blades so that only one contact remains open. **Up to 24 fingers per deck are stocked.** It's called the Multi-Finger Progressive Shorting Type Switch, Daven Type 24-FM.–The Daven Co., 530 W. Mount Pleasant Ave., Livingston, N. J.

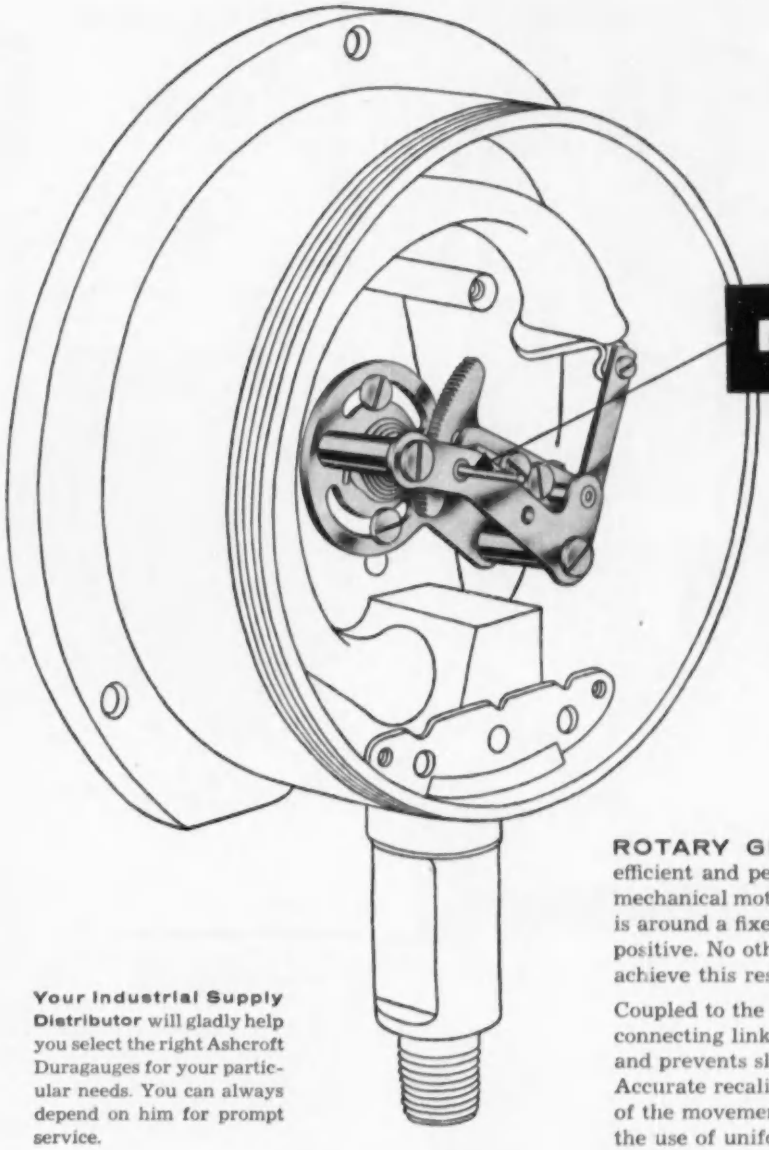
Circle No. 34 on reply card



HIGH-POWERED RELAY: By sealing heavy contacts in a vacuum, the maker of this product can switch up to **22,000 volts at low amperage, or up to 30 amps at up to 250 volts.** It was originally developed for handling spectrographic arc and spark sources, and has spot contacts.–Penta Laboratories, Inc., Santa Barbara, Calif.

Circle No. 35 on reply card

DOUBLE-PRESSURE SWITCH: By mounting two independent pressure switches in one case, Barksdale has come up with a unit that will



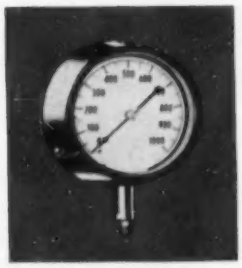
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ROTARY GEARED MOTION, the most efficient and perfect method of transmitting mechanical motion ever developed. Because rotation is around a fixed center, pointer position is always positive. No other type of movement can ever achieve this result.

Coupled to the movement is a one-piece connecting link that guarantees correct calibration and prevents slippage or parting under tension. Accurate recalibration is easy from front or rear of the movement. Universal adjustability permits the use of uniformly graduated dials, thereby facilitating maintenance.

The Ashcroft Duragauge is available with all-stainless-steel movement or stainless steel with nylon bearings and pinion gear. There are case designs and materials, Bourdon tube materials, pressure ranges and dial sizes to meet your service conditions exactly. Save time, trouble and money. Specify the pressure gauges of highest sustained accuracy and durability – Ashcroft Duragauges.

Your Industrial Supply Distributor will gladly help you select the right Ashcroft Duragauges for your particular needs. You can always depend on him for prompt service.



In Canada: *Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario*

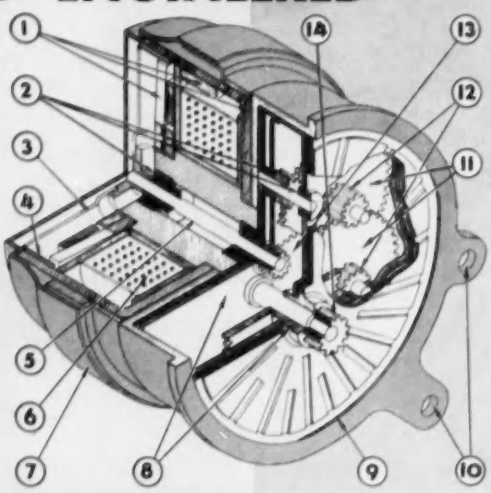
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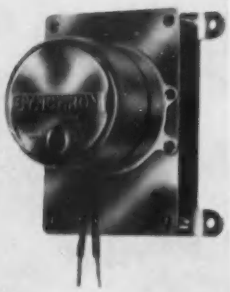
SYNCHRON TIMING MOTORS

Guaranteed to pull 8 in. oz. at 1 RPM; operate smoothly, evenly in any position at temperatures from −40° to +140° F. Start instantly under load. Available in 42 speeds from 0.8 RPM to 600 RPM.

HIGH TORQUE MOTORS available with 20 in. oz. guaranteed torque at 1 RPM.



1. Patented 2-piece field structure with wide and narrow poles; rotor rotates between inner and outer poles; properly shaded with heavy, continuous copper rings; assures maximum starting and running torque.
2. Double bearings in reduction train and on rotor shaft assure smooth operation, sustained accuracy, long wear.
3. Aluminum rotor ring support, light weight, rigid.
4. Patented, hardened steel rotor ring.
5. Oil storage reservoir with patented oil feed to bearings permits motor to operate in any position.
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7. Heavy brass rotor cover.
8. Double bearings on output shaft for long wear.
9. Sealed gear case prevents oil leakage.
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11. Brass gears.
12. Steel pinions. NOTE: Brass against steel assures longer life.
13. Bakelite gear for quiet operation.
14. Output shaft shown equipped with 10 tooth 54 pitch pinion, .130 in. face. Also standard with 10 tooth 48 pitch pinion, .130 in. face; or solid steel shaft ⅛ in. dia. x ⅝ inches. Special drives available.



SYNCHRON TIMING MACHINES

Four basic external assemblies available, in combination with Synchron "610" Motor. Friction clutch eliminates possibility of damaging built-in gear train. Speeds from 10 RPM to 1 RP24H.

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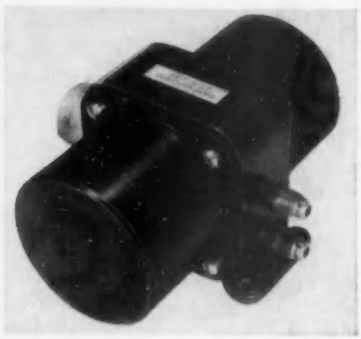
FACTORY REPRESENTATIVES: The Fromm Co., 5254 W. Madison St., Chicago, Ill. • R. H. Winslow Assoc., 123 E. 37th St., New York, N. Y. • Electric Motor Engineering, Inc., 8255 Beverly Blvd., Los Angeles, Cal. • Lawrence Sales Co., Box 13026, Dallas, Texas.

NEW PRODUCTS

signal when pressures rise above ideal limits as well as above safe limits. It comes in three classes of proof pressures: 6-, 30-, and 120-psi, with adjustable ranges of from 0.05 to 100 psi.—Pressure Switch Div. of Barksdale Valves, Alcoa Ave., Los Angeles 58, Calif.

Circle No. 36 on reply card

DETECTORS



PRESSURE POT: A new pressure transducer, using resistance elements of from 2 k to 50 k ohm, is said to be its maker's first excursion into the pressure transducer field. Output is proportional to altitudes from 1,000 to 20,000 ft with the use of both absolute and differential pressure elements. Each element's pot has dual functions as well. Air speed readings of from 205 to 590 knots are also within the instrument's range—Components Div. of Fairchild Controls Corp., 225 Park Ave., Hicksville, N. Y.

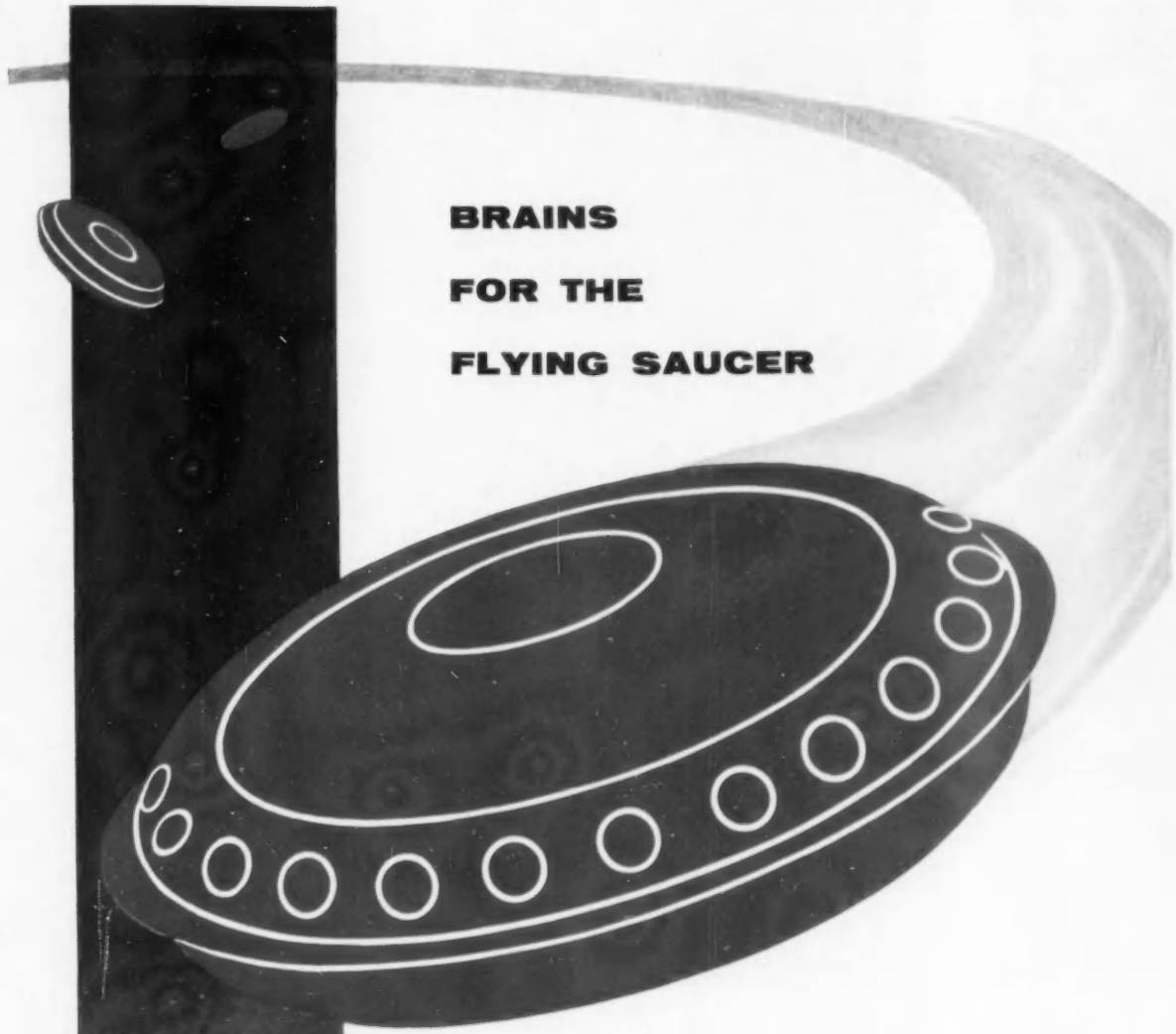
Circle No. 37 on reply card

PRESSURE TRANSDUCER: A thumb-sized flush-diaphragm pressure transducer uses a bridge circuit for a 80 mv max output. The stainless steel device is offered in ranges from 0 to 15 to 0 to 5,000 psi absolute. Natural frequency is 5,000 cps.—North American Instruments, Inc., 2420 North Lake Ave., Altadena, Calif.

Circle No. 38 on reply card

LEVEL INDICATOR: An improved level indicator **for granular or powered material** detects the presence of solids by the restraint offered to a rotating paddle. It will operate at temperatures up to 300 deg F.—The Fuller Co., Catasauqua, Pa.

Circle No. 39 on reply card



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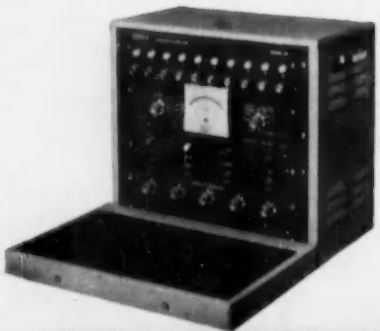
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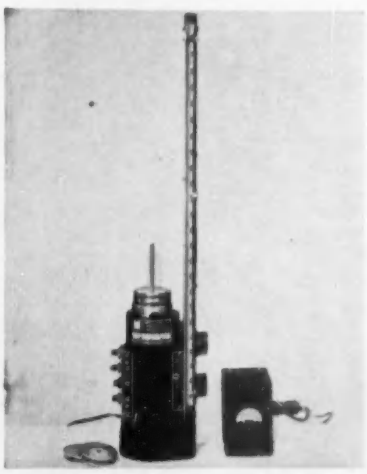


ALTITUDE SWITCH: Adjustable for any setting in the 2,000-to-5,000-ft range is a new altitude switch with 10 amp contacts. It's accurate to within 2 per cent—Aero Mechanisms, Inc., Box 34628, Los Angeles, Calif.

Circle No. 40 on reply card

PNEUMATIC TRANSMITTER: To be used for measuring temperature or pressure, a new pneumatic transmitter converts temperatures of from minus 375 to 1,000 deg F or pressures of from 40 to 600 psi to a standard 3-to-15-psi output. The instrument operates on the force-balance principle, which means **that full scale deflection of the primary measuring element is only a few millionths of an inch.** A small stainless-steel bulb acts as the temperature pickup.—Industrial Controls Div. of Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

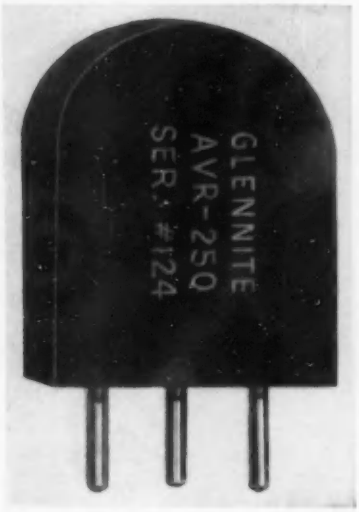
Circle No. 41 on reply card



PRESSURE-TRANSDUCER TESTER: The unique construction of a new pressure indicator **enables reading to within 0.31 psi through a range of from 0 to 600 psi.** One of

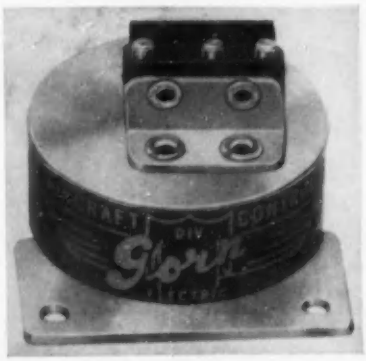
its features is electrical output for recorder operation. It uses no springs, bellows, diaphragms, or Bourdon tubes, and tolerates sudden pressure surges. The ultra-sensitive device is intended for use by pressure pickup makers as a calibrating source.—Manning, Maxwell & Moore, Inc., Stratford, Conn.

Circle No. 42 on reply card



FLUTTER ACCELEROMETER: Designed for flutter and vibration detection of small and light components, a new miniature vibration pickup has less than 0.99 cu in. of volume, and is **designed for 500 to 1,500 cps inputs,** yielding 30 millivolts full scale per volt input. Response is said to be within 3 per cent up to 300 cps.—Gulton Mfg. Corp., Metuchen, N. J.

Circle No. 43 on reply card



BAROMETRIC PRESSURE SWITCH: The little switch seen here can be precalibrated **for operation at any altitude from 1,000 to 50,000 ft.** —Aircraft Control Div. of Gorn Electric Co., Inc., Stamford, Conn.

Circle No. 44 on reply card

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drive counters in new Hycon digital instruments

Direct-reading, 3-digit display gives quick, accurate data for users of the new Hycon digital voltmeter, shown below, and its companion instrument, the Hycon digital ratiometer. To drive these counters, Hycon Mfg. Company selected high-torque Barber-Colman BYAE reversible motors designed for control by electronic circuits with impedance coupling. Low-inertia rotors permit fast reversing and follow-up. Just another example of how Barber-Colman supplies the right motor for the job!



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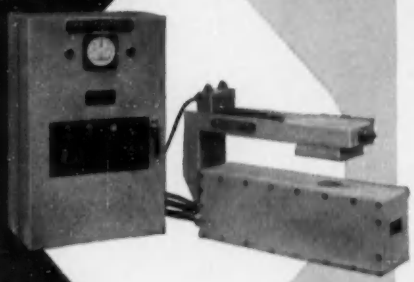


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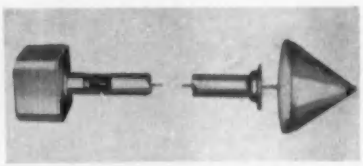
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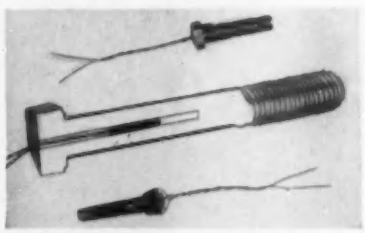
LOAD DETECTOR: Weights of up to 10,000 lb are detectable by 2-in.-diam **load cells** recently marketed for space-shy installation.—Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.

Circle No. 45 on reply card



FLUID-LEVEL TRANSMITTER: For use with highly corrosive fluids, a new level transmitter-detector **provides a vacuum signal proportional to liquid height.** By placing its float in a stillwell, the instrument can be used as an indicator of flow rate.—Fischer & Porter Co., 55 Jacksonville Rd., Hatboro, Pa.

Circle No. 46 on reply card



LOAD-SENSITIVE SCREWS: By placing **tiny strain gages in screws and bolts,** the maker of this item equips it for service where the even distribution of screw loads is important. However, the product offers a uniquely simple way to electrically detect loads of any character on bolted assemblies.—Polyphase Instrument Co., 701 Haverford Rd., Bryn Mawr, Pa.

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LOW-PRESSURE DIAPHRAGM MANOMETER: For use **where ranges do not exceed 4 in. of water** and static pressure is not over 5 psig is a large stainless-steel convoluted diaphragm manometer, developed for actuating recording, indicating, or con-

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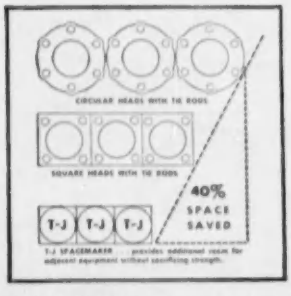


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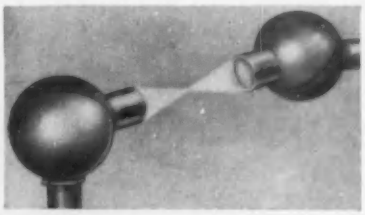
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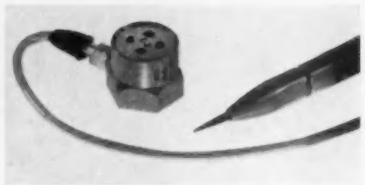
trolling instruments.—Taylor Instrument Companies, 95 Ames St., Rochester 1, N. Y.

Circle No. **48** on reply card



PHOTOELECTRIC PAIR: This design seems worth attention. One watertight sphere contains the light source, the other the photocell, amplifier, and pilot relay. To simplify matters to the extreme, **each sphere mounts right on the end of the electrical conduit.** — Hancock Industries, 6711 S. Sepulveda Blvd., Los Angeles 45, Calif.

Circle No. **49** on reply card



SHOCK ACCELEROMETER: The natural frequency of this acceleration sensor is 70 kc, with **linear output to at least 14 kc.** Output is 3 millivolts per g, from a piezoelectric pickup linear up to 30,000 g's. The 0.35-oz weight is not likely to modify the mass characteristics of many structures.—Endevco Corp., 161 E. California St., Pasadena, Calif.

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POWER SOURCES

AIRCRAFT POWER SUPPLIES: 200 volts three-phase, 400 cycles in, and out of the Chatham type 28V100 power supply comes 28 vdc, **at 100 amps. It weighs under 17 lb** and features fair regulation against both line and load variations.—Aircraft Instrument Dept. of Chatham Electronics, Livingston, N. J.

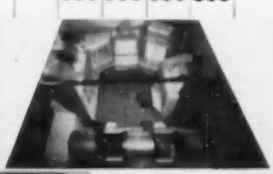
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● Manufacturing ●● Manufacturing and product development ●●● Manufacturing, product development and research □●● Pilot manufacturing, product development and research

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	GPE CAPACITIES
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●●●	●	●	□●●		●●●					●●●		●●●	Automatic Computers and Components
●●●	●	●●	●●●		●●			●		●			Radar, Microwave, Ultrasonics
	●●●		□●●				●●	●●●	●●●		●●●		Motion Picture and Audio Equipment
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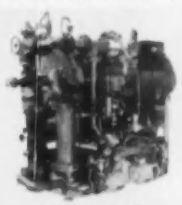
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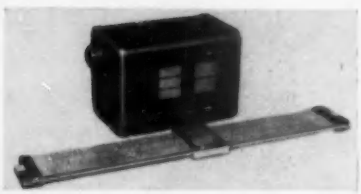
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REFERENCE SOURCE: A plum-sized can takes inputs of from 95 to 135 volts at from 370 to 430 cps, at 10 ma, to yield a 6.2-volt output (with other voltages available). It's regulated to within 0.1 per cent and provides up to 10 ma. **Circuitry is all-magnetic.** In quantities the price is $35 each. – Stator Electric Corp., 46-25 58th St., Woodside 77, N. Y.

Circle No. 53 on reply card



VOLTAGE REFERENCE: These tubeless voltage references **take care of short circuit conditions without blowing fuses,** and input variations from 35 to 135 volts, **and produce up to 1 amp.** Input is 25 va at 400 cycles and output is up to 20 volts dc.–Timely Instruments & Controls Corp., 1645 W. 135th St., Gardena, Calif.

Circle No. 54 on reply card

SUPPLY LINE: Voltages of from 50 to 375, currents of from 1 to 3 amps, regulation to within 0.1 per cent, and **transient response to within 0.1 millisec,** are the outside characteristics of a new H series of adjustable power supplies.–Universal Electronics Co., 1720 22nd St., Santa Monica, Calif.

Circle No. 55 on reply card

NO-WATER BATTERY: A new cell, said to be the first truly solid-state battery, can furnish **up to 200 volts from a 1-cu-in. package.** Shelf life of 10 years is predicted. Currents are low, in the microamp range, but cost is a few cents per volt, and higher current

models are foreseen.–Battery Div. of P. R. Mallory & Co., Inc., North Tarrytown, N. Y.

Circle No. 56 on reply card

NUMERICAL IN NATURE



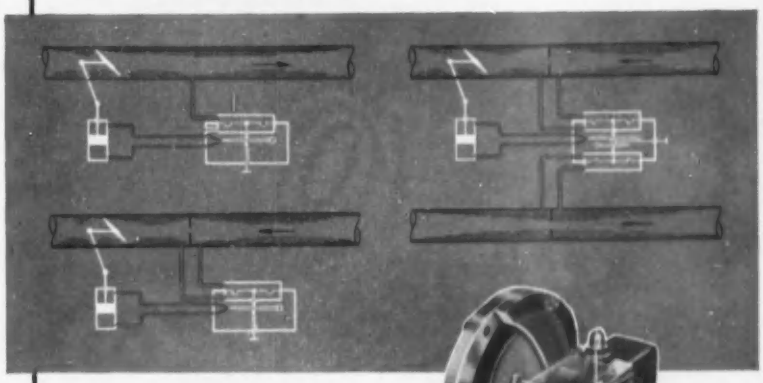
DIGITAL PRINTOUT: Not satisfied with the printout alone, this machine's designers have put together something that will add, subtract, and totalize on input pulses of from 19 to 25 milliseconds. Operating speed is 60 lines per min with an output of 11 decimal places.–Remington Rand Univac, 1902 W. Minnehaha Ave., St. Paul W4, Minn.

Circle No. 57 on reply card

PULSE BURST GENERATOR: A group of new pulse generators provides a string of accurately spaced and numbered pulses for each triggering input pulse. Three models are provided, from 1 to 1,024 pulses per burst, with spacing between pulses from 20 microsec to 32.7 millisec. Number or spacing can be variable or factory set. The generators are encased in a shoe-box-size enclosure, with plug-in terminals. Output can be either 18 volts negative with 25 ohms impedance, or 35 volts positive (switch selected) with 100 ohms impedance. Pulses are 1.5 microsec duration, with 0.15 microsec rise time. Triggering pulse can be from 0.5 to 50 volts in amplitude with a duration of at least 0.5 microsec; 115 vac 60 cps powers them.–The Jacobs Instrument Co., Bethesda 14, Md.

Circle No. 58 on reply card

THE "Jet-Pipe" AGE IS HERE...
FOR PRESSURE, FLOW, COMBUSTION OR RATIO CONTROL





and so is the
ASKANIA
Jet-Pipe Regulator

...the simplest accurate long-life solution to any regulator problem

• Check your most desirable specifications for the IDEAL regulator to control pressure—flow—combustion—proportion—other variables.

Do they include

1 Rugged Construction **2** Dependability **3** Long Life **4** Accuracy **5** Speed **6** Inexpensive Maintenance **7** Unimpeded Operation in Freezing Weather **8** Freedom for use ANYWHERE?

All these features are common to all ASKANIA Jet-Pipe Regulators.

From Minute Signal to POWERFUL FORCE

The real magic behind the Jet-Pipe Regulator is the power which can be initiated by a minute signal—the degree to which the signal can be amplified—and the speed and accuracy with which it can be transmitted. The conversion of kinetic energy (velocity pressure) into potential energy (static pressure) is an important factor which multiplies the dependability you can expect in every ASKANIA control. The heart of ASKANIA Regulators—the Jet-Pipe—is practically frictionless. Bearings are continuously immersed in oil. Condensation and freezing are impossible. In every way, ASKANIA Regulators are designed and built for continuous, trouble free service over the years.

Applicable to these Controlled Variables:

PRESSURE (Gage, Absolute & Differential) • DRAFT • COMBUSTION • FLOW LEVEL • DEPTH • RATIO • SPEED • DENSITY • CONSISTENCY • EDGE POSITION AND OTHERS

What is your problem? For further information on the type of regulator control which best fits your operation, send today for Bulletin No. 139 and 155. Write the ASKANIA REGULATOR COMPANY, *266 East Ontario St., Chicago, Illinois.*

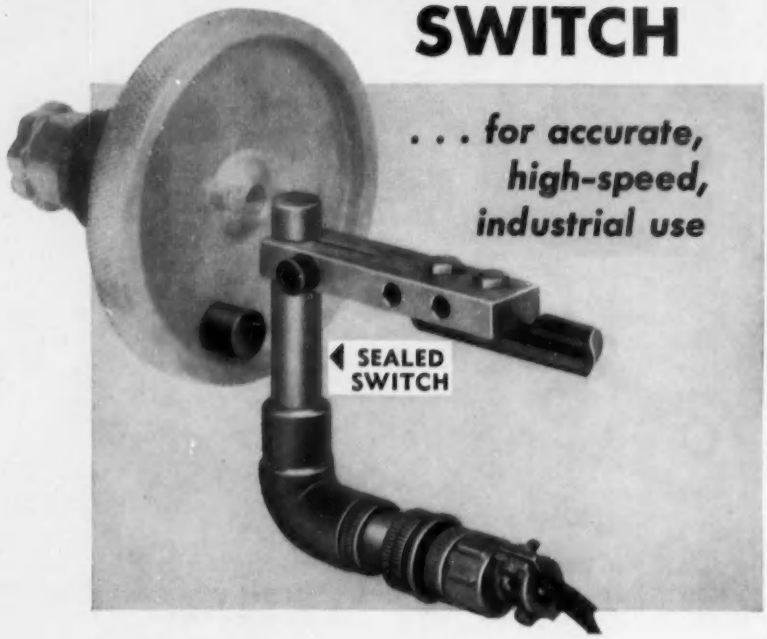
ASKANIA REGULATOR COMPANY

"CONTROLS FOR INDUSTRY"

HYDRAULIC, ELECTRONIC CONTROLS & SERVOS, GENERAL SYSTEMS, ENGINEERING & COMPUTER SERVICE, VALVE ACTUATORS & CYLINDERS

A Subsidiary of General Precision Equipment Corporation

POST Decitron MAGNETIC SWITCH



Positive 'sensing' from zero to 100 cycles per second

The Post model MH-2 is a magnetically operated high-speed switch which is controlled by the proximity of a magnetic field. When the magnet reaches the face of the sealed switch, there is a clean 'make', or contact, and as the magnet moves away, a positive 'break' occurs. No lag . . . no jumping.

Unique in operation, the MH-2 works fully as well at low speeds. For example, a clearly defined 'make' and 'break' is possible at any speed range from zero up to 100 cycles per second. The MH-2 has a 'life' of over 30 billion cycles.

Post's MH-2 is an ideal sensing device for actuating electronic and mechanical counters, controls, solenoids, relays, and other electrical and electronic circuits. Write Post for descriptive literature "M" today.

See us at Booth #902 Design Engineering Show May 14-17 — Philadelphia, Pa.

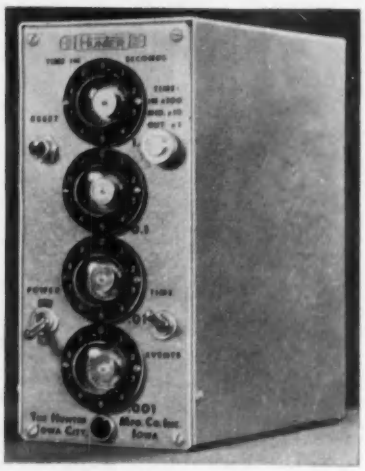
POST

Electronic Products Division

POST MACHINERY CO.

Elliott Street—Dept. M Beverly, Massachusetts

NEW PRODUCTS



ELECTRONIC COUNTER: Little larger than a desk dictionary, a new 2,000-cps counter indicates to four digits by glow tubes. As an interval timer, it works with a motor and photocell circuit to measure in intervals of 1/10, 1/100 or 1/1,000 sec—Hunter Mfg. Co., 930 S. Linn St., Iowa City, Iowa.

Circle No. 59 on reply card



NAVIGATION COUNTER: A numerical navigation readout provides the words "left" and "right" in addition to numerical indication. The words pop up whenever the count goes through the zero point.—Durant Mfg. Co., 1929 N. Buffum St., Milwaukee 1, Wis.

Circle No. 60 on reply card

DELAY LINE: Tapped every two microsecs, a new delay line offers a total delay of 200 μ sec with an impedance of 400 ohms and a rise time of 4 μ sec.—Components Div. of Litton Industries, 215 S. Fulton Ave., Mt. Vernon, N. Y.

Circle No. 61 on reply card

Thomas A. Edison Inc.'s

PERSONAL DEMONSTRATION

shows how you can

INCREASE PLANT PRODUCTION



Our representatives throughout the nation are ready to demonstrate *a complete* Omniguard system right at your plant or office.

Takes Only a Few Minutes to Prove Simple Omniguard System Protects Bearings and Processes; Cuts Down Time; Increases Equipment Life

Just take a few minutes to prove to yourself how Omniguard can make it possible for you to operate your equipment at peak production rates without fear of breakdowns . . . how this simple temperature detection system gives you ample opportunity to prevent bearing failures or to keep process temperatures within limits.

RECORDS REVEAL FAILURES COSTLY

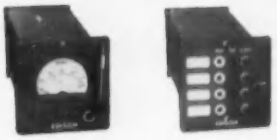
Many operators—after a record check—are astonished to find how much bearing breakdowns have been costing them in maintenance and lost production. They see that the cost is often many times the expense of installing Omniguard.

COMPLETE 4-POINT SYSTEM FOR LESS THAN $500

Consider the thousands of dollars involved in equipment and production output. Contrast this with the fact that one Omniguard unit costs less than $500. And because of its simplicity, installation costs are also low.

SIMPLE, DEPENDABLE

Omniguard has no electronic or moving parts. It is the most dependable system available today. Modular in design, each unit gives you four-point detection. You can add as many as you need . . . as you need them.



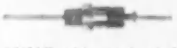
The modular indicator and monitor, with their mounting brackets, and the resistance temperature detectors, are all you need for a continuous operating analysis of remote process or bearing temperatures.

Resistance Temperature Detectors

These are just four of the many different types of temperature detectors produced for varied applications of the Omniguard system.



The 242P for high temperatures (to 1300°F.)



The 166NC with pre-loaded sensitive tip specially designed for bearing protection.



The 230N for general purpose industrial use (stem-sensitive).



The 235N90-35 for fast response in corrosive service.

A Partial List of Present Users

American Blower Corp.
City of Chicago
Combustion Engineering, Inc.
DeLaval Steam Turbine Co.
Eastman Kodak Co.
Esso Standard Oil Co.
Florida Power & Light Co.
General Electric Co.
Hercules Chemical Co., Inc.
I-T-E Circuit Breaker Co.
North American Aviation, Inc.
Public Service Electric & Gas Co.
Republic Steel Corporation
Sun Oil Company
Union Carbide & Carbon Corp.
Westinghouse Corp.

Thomas A. Edison

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Please have representative call for appointment at no obligation to me_____

Please send detailed information_____

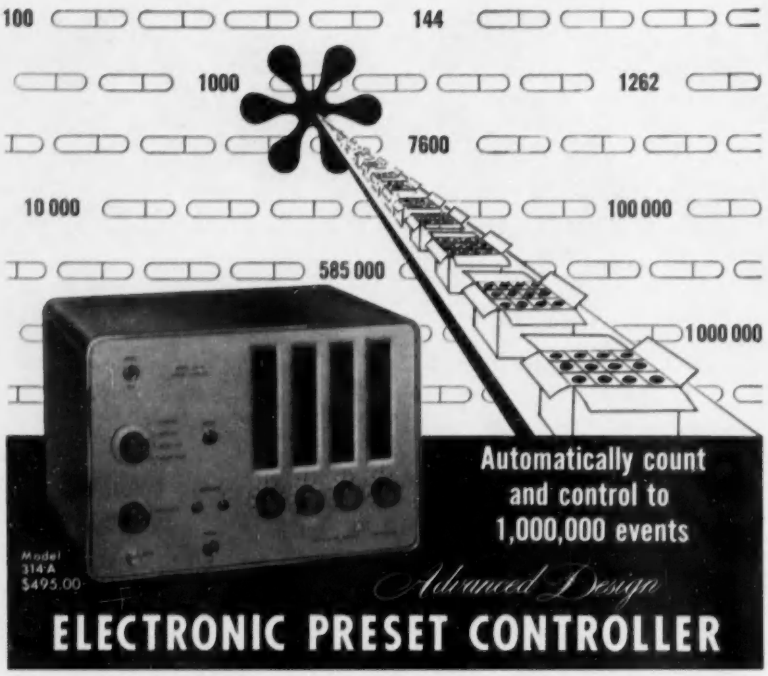
Name_____

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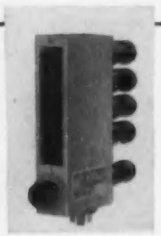


The CMC Model 310 Series Preset Controllers are designed as high speed direct reading electronic counters of the coincident type which will control any operation or activate an alarm after a preselected total count has been reached.

***A few of the many applications are batching and packaging of pills, bottles, bottle caps, canned goods, pen points, machine parts, electronic components, etc., in exact preselected quantities; controlling the exact length of stock in cutting operations; and control of high speed machinery.** Any electrical, mechanical or optical events which can be converted into electrical impulses can be counted and controlled. Devices to effect this conversion may be photocells, magnetic coils, switches, and suitable transducers for pressure, temperature, velocity, acceleration, displacement, etc.

SPECIFICATIONS						FEATURES
	312A	313A	314A	315A	316A	COINCIDENT TYPE ABSOLUTE ACCURACY DIRECT SETTING DIRECT READ-OUT EXCEPTIONAL VERSATILITY HIGH SPEED RELIABLE RUGGED ECONOMICAL SMALL SIZE
Decades	2	3	4	5	6	
Count Capacity	100	1000	10,000	100,000	1,000,000	
Counts per Second	0 to 100,000 (as totalizing counter)					
Recycling Rate	50,000 counts per second (as preset counter)					
Input Sensitivity	0.05 volts rms: 10-100,000 cps 0.07 volts rms: 1-10 cps Positive Pulse Rise Time: ½ volt or more per sec.					
Input Impedance	0.5 megohm, 50 mmf					
Accuracy	Absolute					
Output	60 volt positive pulse, 10 microseconds duration (negative pulse optional)					
Output Relay Contacts	5 amps, 117 volts, non-inductive load Normally open or normally closed (with indicator lamps) Can be switched out					
Relay Hold Time	Automatic: Continuously variable from 0.1 to 1 second Manual: Lock until release					
Auxiliary Power	6.3 volts ac @ 3 amps; +225 volts dc regulated @ 50 ma; —150 volts dc regulated @ 5 ma.					
Power Requirements	117 volts ± 10% 50-60 cycles 100-150 watts depending on model					
Dimensions	13" W x 8¾" H x 13" D				16¼" x 8¾" x 13"	
Net Weight	20 to 28 lbs. depending on model					
Finish	Panel: Light grey baked enamel Case: Dark grey baked enamel					
Data Subject to Change Without Notice						

The direct reading Model 101A Preset Decade Counting Unit is designed to provide an output pulse at a selected number at rates in excess of 50,000 counts per second. They are capable of counting at a 100,000 cps rate if reset is not required. These units are readily connected in cascade in order to emit a pulse at any desired count. Typical applications are batching, sorting, packaging, automatic counting and control, frequency division, generation of precise delays, etc.



Model 101A $75.00

Write for complete catalog and prices.

Computer-Measurements Corporation

5528 Vineland Avenue, North Hollywood, Calif. Dept. 84-E

CC-14

NEW PRODUCTS

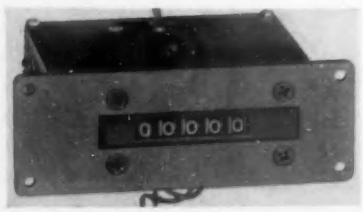


BI-DIRECTIONAL COUNTER: Actuated at up to 60 cps, a new counter adds or subtracts pulses to 5 or 6 digits, with some models actuating switches at preset numbers.–Nemeth, Inc., 2223 S. Carmelina Ave., Los Angeles 64, Calif.

Circle No. 62 on reply card

IMPROVED DIODES: A new line of subminiature germanium diodes is said to have characteristics far superior to older types. Some types, it is claimed, will **handle a maximum of 150 volts, and yet pass a minimum of 400 ma** at 1 volt, with reverse leakages as low as 20 microamp max at minus 100 volts.–Radio Receptor Co., Inc., Brooklyn, N. Y.

Circle No. 63 on reply card



ADD-SUBTRACT COUNTER: Designed for panel mounting, a new electrically operated add-subtract counter, Model 5-Y-8602-MF, accepts up to **500 counts per min** of 110 vac 60 cycle current.–Durant Mfg. Co., Milwaukee 1, Wis.

Circle No. 64 on reply card



Now Available...

FIRST HF TRANSISTORS

now in production, meeting

Army Signal Corps Standards



A wide variety of military equipment, once impossible to transistorize due to frequency limitations of available transistors, is now being developed with Philco Surface Barrier Transistors.

PHILCO SBT

SURFACE BARRIER TRANSISTORS

(Type 2N128 and 2N129)

Meet MIL-T-12679A Military requirements

Check These Features

- **High frequency performance**
- **Extreme reliability**
- **Uniformity of characteristics**
- **Rigid quality control**
- **Minimum battery drain**
- **Low leakage currents**
- **Low operating voltage**
- **Absolute hermetic seal**
- **Meet MIL-T-12679A Military requirements**

Now available for large volume military and industrial applications . . . the high frequency Philco Surface Barrier Transistors that were developed for the Army Signal Corps to meet the stringent requirements of field use in military electronics equipment. Advanced precision techniques used in fabricating the Philco Surface Barrier Transistors make possible rigidly controlled automatic manufacture with its resultant uniformity, reliability and high volume production. These reliable transistors point the way to new fields in transistorization. Make these reliable high frequency Philco Surface Barrier Transistors part of your forward looking plans.

For complete technical information on these High Frequency transistors write Dept. CE-3, LANSDALE TUBE CO., Lansdale, Pa. A DIVISION OF PHILCO CORP.

PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

INSTROF

CONTINUOUS SUPPORT AND PROTECTION FOR INSTRUMENT TUBING



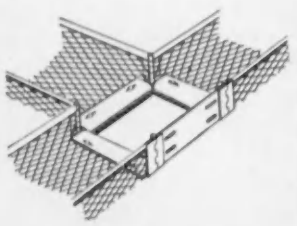
Tubing may readily be run to individual instruments or panels as needed.

Delicate instruments quickly become useless without adequate tubing support. Instrof provides a flexible, simple-to-install system for maximum efficiency and dependability at minimum cost. Famous Pin-Type Coupling available for wide range of standard fittings and runs.

Instrof is a system of Prefabricated Expanded Metal Trough specifically designed for rigid, continuous support and protection of instrument tubing. All parts are hot-dip galvanized for long life. Widths of 3", 6", 9", 12", 18", and 24", lengths of 8', 10', and 12', and a complete line of fittings allow the Instrof system to meet the demands of virtually any plant layout.

Exclusive Pin-Type Coupling speeds installation and reduces labor costs. Just two coupler pins and a bottom plate are needed to complete a connection.

Drop-out is one of many standard fittings that keep an Instrof system flexible, yet simple to install. Expansion is a simple matter with an Instrof system as additional tubing may be laid in existing trough.



INSTROF CORP.
DIVISION T. J. COPE, INC.
COLLEGEVILLE 20, PENNSYLVANIA

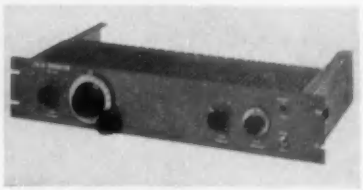


NEW PRODUCTS



PULSE TRANSFORMER: Type PT-100 has four windings and plugs into a miniature Noval socket. Each winding has 100 turns with resistances ranging from 3½ to 5 ohms per winding.–Berkshire Laboratories, 826 Bank Village, Greenville, N. H.

Circle No. 65 on reply card



PULSE GENERATOR: Production of ½-sine waves varying in duration from 0.03 to 0.07 microsec in frequencies ranging from 1.6 to 10.4 is the business of a new high-frequency pulse generator. – Burroughs Corp., 1209 Vine St., Philadelphia 7, Pa.

Circle No. 66 on reply card

PULSE DELAY: Delays from 0.1 microsec to 999.9 microsec precede the triggered pulse from a new delayed pulse generator.–Orbitran Co., P. O. Box 635, Lakeside, Calif.

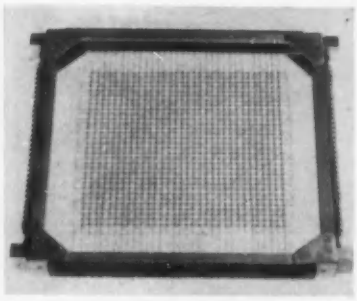
Circle No. 67 on reply card



RATEMETER FOR CONTROL: Model 2850 ratemeter is slated for industrial applications requiring de-

tection of radioactivity in control setups. It provides an **output voltage proportional to count,** as well as loudspeaker and meter indication of input. Integration times range from 2 to 50 sec, with inputs up to 100,000 pulses per min.–Berkeley Div. of Beckman Instruments, Inc., 2200 Wright Ave., Richmond 3, Calif.

Circle No. 68 on reply card

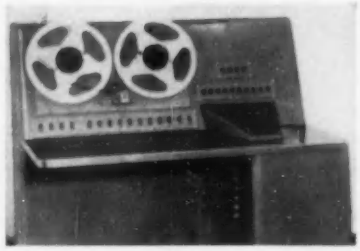


MAGNETIC CORES: A new line of standard magnetic core memory planes have the following frame sizes: 10 by 10, 16 by 16, 32 by 32, and 64 by 64 cores. They have the conventional **X, Y, Z and sensing windings** through each core.–General Ceramics Corp., Keasbury, N. J.

Circle No. 69 on reply card

COUNTS DOZENS: A new counter's reading **indicates dozens instead of units.** The last two digits of the counter indicate the count in the dozen being totalized. It's electrically operated but has manual reset.–Production Instrument Co., 704-20 W. Jackson Blvd., Chicago 6, Ill.

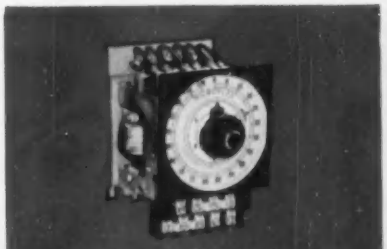
Circle No. 70 on reply card



KEYBOARDING MAGNETIC TAPE: Keyboard preparation of magnetic tape **for computer inputs** is handled by the Codescriber. Automatic function buttons call up repetitive data and sub-routine notations.–Logistics Research, Inc., Redondo Beach, Calif.

Circle No. 71 on reply card

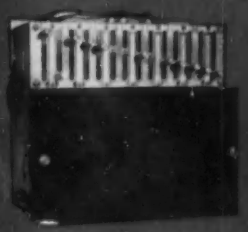
EAGLE
Timers and Counters
VITAL COMPONENTS IN MODERN AUTOMATION



MICROFLEX RESET TIMER
Micrometer dial for precision adjustments. 150+ operating arrangements.



CYCL-FLEX RESET TIMER
With sealed dial, holding contacts, progress pointer for panel mounting.



MULTIFLEX RESET TIMER
For sequence operation of several circuits — each adjustable.



FLEXOPULSE REPEAT CYCLE TIMER
ON-OFF time independently adjustable on calibrated scale.



MULTIPULSE REPEAT CYCLE TIMER
Provides sequential or programmed operation of 2 to 12 circuits.



MICROFLEX RESET COUNTER
Trips switches open or closed after preset number of counts. Electric reset.

Represented above are but a few of the complete line of popular EAGLE Industrial Timers and Counters.

Models are available in a wide range of modifications to fit your particular application. Modern compact design and precise construction of these EAGLE components has won them an enviable coast-to-coast reputation for accuracy and long service-free life of operation. Write us about your needs.

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Eagle timers save time . . . save money

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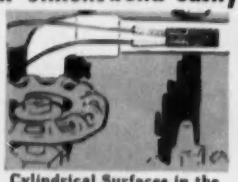


RESISTANCE THERMOMETER ELEMENTS

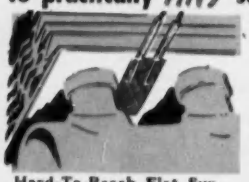
For Quick, Low-Cost

SURFACE TEMPERATURE MEASUREMENT and CONTROL

RdF Stikons bond easily to practically *ANY* surface *ANYWHERE*



Cylindrical Surfaces in the Food, Chemical, and Petroleum Processing Industries, utilizing existing installations.



Hard-To-Reach Flat Surfaces Inside Ducts and Heat Exchangers in the Aircraft, Automotive, and Chemical Industries without affecting the flow of the fluids.



Rounded Surfaces on Engine Cowls in the Aircraft Industry with minimum obstruction to airflow.

Used for reasearch and manufacture in all fields of temperature measurement and control, an RdF Stikon consists of a temperature-sensitive grid of very fine nickel wire bonded into a paper-thin wafer of flexible, insulating material. Bonded by cement to almost any surface anywhere, an RdF Stikon is unaffected by shock or vibration. Its response to temperature change is extremely fast and amazingly accurate. The thinness of the RdF Stikon (.005" to .010") opens up applications difficult or impossible with other thermal-sensing elements.
In addition to the standard RdF Stikons tabulated below, special resistance-thermometer elements are tailored to specific customer needs.

SUMMARY OF CHARACTERISTICS

Type	Resistance at 70°F (ohms)	Temperature Range F°	Wafer Material	Size (Inches)
BN-1	81.7	—100° to +300°	Bakelite	½ x 1½ x .005
BN-3	50.	—100° to +300°	Bakelite	5/16 x ¾ x .006
BN-4	200.	—100° to +300°	Bakelite	5/16 x ⅞ x .006
PN-1	50.	—100° to +180°	Paper	5/16 x ¾ x .006
PN-2	200.	—100° to +180°	Paper	5/16 x ⅞ x .006
SN-1	100.	—100° to +500°	Silicon-Glass	5/16 x 1 7/16 x .010

Send for our FREE Temperature Measurement and Control Brochure Today.

ACRA

ARTHUR C. RUGE ASSOCIATES, INC.

755 CONCORD AVENUE

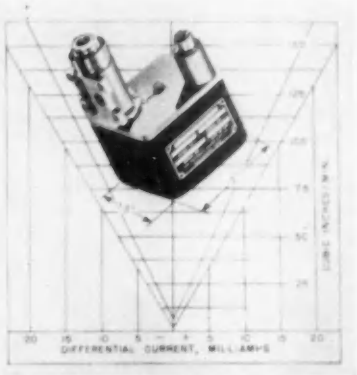
CAMBRIDGE 38, MASSACHUSETTS

NEW PRODUCTS

SILICON DIODES: Eight new diodes are on the market with **voltage ratings from 15 to 225.** Their designations end with the letter A, but otherwise they are similar to previously marketed models with lower current ratings.—Raytheon Mfg. Co., 55 Chapel St., Newton 58, Mass.

Circle No. 72 on reply card

CONTROL VALVES



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(100) PULP AND PAPER PROCESSING. Fischer & Porter Co. Bulletin 90-130-10, 32 pp. A discussion of the wood-pulp-to-paper process with F&P's instruments front and center in every stage. Special attention to slush stock flow rate meter, stock control valve, consistency regulator.

(101) PROCESS CONTROL. Fischer & Porter Co. Bulletin 90-130-24, 4 pp. F&P describes a data reduction and logging system it installed in a plant that does the kind of work covered in item 100 above. Functional diagram shows how variables, data, and data sources are controlled and used.

(102) COPYING LATHES. Vereinigte Drehbank-Fabriken, Germany. Catalog VDF105, 80 pp. VDF does itself an injustice by calling this a "booklet." It's a book in every sense, and a beauty. Some of the elegant photos trace the history of copy turning. Others illustrate the electro-hydraulic Unicop lathe. The running text, well-written and informative, doesn't shy away from fundamentals, e.g., Unicop's accuracy of plus or minus 0.0002 in. cross and plus or minus 0.001 in. longitudinal. Requests should be heavy.

(103) ALLOY CHARTS. Electric Steel Foundry Co. Catalog 175-A, 100 pp. This may prove a find for designers looking for corrosion resistant data and chemical composition and mechancial properties of alloys and stainless steels.

(104) MAGNETIC REMANENCE. The Indiana Steel Products Co., Indiana Permanent Magnet Manual 5, 12 pp. Covers selection of cast, sintered, duct, and formed PM's the hysteresis loop, demagnetization curve, temperature limitations, directional properties, incremental permeability, etc.

(105) PARTICLE ACCELERATION. High Voltage Engineering Corp. Bulletin E, 34 pp. Tells how radiation energy can be used in food preservation, drug sterilization, plastics. High Voltage's electron accelerators, their installation and use, are described.

(106) LIMIT SWITCHES. R. B. Denison Mfg. Co. Catalog 955, 12 pp. Describes seven models and 19 contact arrangements of Loxswitch heavy-duty units said to last 3-4½ times longer than comparable types. Data deal with housings, wiring, ratings, electrical characteristics.

(107) CONTROL INSTRUMENTS. James G. Biddle Co. Bulletin 19-56, 16 pp. Covers devices for testing and speed-measuring, controlling, signaling, monitoring, protection and frequency matching.

(108) V-BELT DRIVES. Allis-Chalmers Mfg. Co. Bulletin 20E8297, 36 pp. A thorough treatment of this basic method of power transmission has been needed for a long time, A-C believes. In complying, it shows first and refined formulas for determining type of belt, illustrates applications, defines terms.

(109) ALLIS-CHALMERS LINE. Booklet 25B6057, 9 by 4 in. This A-to-Z directory of A-C products literally covers that range: from absorption equipment to Zeolite softeners.

(110) DATA REDUCTION. Radiation, Inc. "A High-Speed Analog-to-Digital Data Reduction System", 6 pp. Describes that part of an Air Force telemetering system that converts data to a digital form directly acceptable by high-speed computers. Handles 32 channels of data.

(111) CUT-OFF REGISTER. General Electric Co. Bulletin GEA-4371A, 12 pp. Deals with two control systems for printing and describes components: the web-scanner, photoelectric selector switch, con-

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trol panel, and fractional horsepower dc correcting motor.

(112) PUNCH-PRESS POSITIONING. General Electric Co. Bulletin GET-2509, 8 pp. Tells how an 80-ton rotary turret press that punches a 6-in. hole in ½-in. manganese steel was made automatic. Controlled: two linear motions, a rotary turret, and the machine cycle.

(113) COMPUTER TUBES. General Electric Co. Booklet ETD-1140-P, 50 pp. Outlines GE's computer-tube program, gives full technical data on the five tubes in the line, and reviews special design considerations and applications.

(114) FLOW IMPEDANCE VALUES. Statham Laboratories, Inc. "Instrument Notes", January 1956. Develops equations and graphs for determining flow resistance values and effective mass of flow of viscous fluids in circular tubes and between parallel plates.

(115) EXPANSION JOINTS. Magnilastic Div. of Cook Electric Co. Catalog 53. 24 pp. Two good tables here are Rating & Selection and Steam & Expansion. These describe pressure-formed Hydrolastic tubing units of copper, stainless steel, carbon steel, monel, or nickel.

(116) THREE-D CAMS. The Parker Stamp Works, Inc. Bulletin, 4 pp. This reprint from a 1952 issue of *American Machinist* traces the design and construction of a control cam serving as the "nerve center" of an air-borne computer for supersonic speeds.

(117) READ-RECORD HEADS. Librascope, Inc. Bulletin, 4 pp. Describes encapsulated heads with low record current and high read-back voltage for large diameter/flat drums and general purpose drums, all with sintered ferrite cores with low capacitance and low resistance windings.

(118) SORENSON STANDARDS. Sorenson & Co., Inc. Condensed catalog, 4 pp. These specifications for power supplies, voltage regulators, voltage reference sources, frequency changers, and other instruments cover regulation accuracy, input-output voltages, ripple, recovery time, etc.

(119) SILICON POWER RECTIFIERS. Sarkes Tarzian, Inc. Gives data on rectifiers rated from 500 milliamps at 50 volts to 3 amps at 1,000 volts, and allowing cell temperatures as high as 150 deg C. Efficiency, size, construction, operation, and leakage current noted.

(120) AIR CONTROL VALVES. Automatic Valve, Inc. Bulletin, 4 pp. A guide, in quick-reference form, to 17 types of valves arranged in in-line two-way, three-way, and four-way classes.

(121) TIME DELAY RELAYS. The A. W. Haydon Co. Bulletin A.W.H. TD 402, one sheet. Features the proportional-delayed-reset characteristic of three Haydon units that operate in a range of from minus 65 to plus 160 deg F under vibration of 5-55 cps with 10-g max acceleration and 30-g shock.

(122) SPEED TRANSMISSION. Revco, Inc. Catalog 20MO156, 12 pp. Describes the Zero-Max "infinitely variable" speed reducer which can go to true zero rpm by withholding lateral motion from its connecting linkages. Output speed thus starts at zero and goes up to ¼ the satisfactory input speed of 2,000 rpm.

(123) O-RING SIZES. Rubber Products Div. of The Parker Appliance Co. Bulletin 5701, 12 pp. Contains condensed cross-reference charts of size numbers and dimensions for 296 Parker O-rings for sealing applications.

(124) LIGHT-SCATTERING PHOTOMETER. Phoenix Precision Instrument Co. Bulletin B-P1000 A, 24 pp. An attractive presentation of a wad of information on the latest version of an absolute instrument for determining high molecular weights and small particle size.

(125) KAY LAB INSTRUMENTS. Kay Lab. Catalog, 6-pg. gatefold. Kay Lab plays up its chopper amplifier, whose drift is said to be 1/1,000 of the inherent drift in conventional direct-coupled amplifiers.

(126) VOLTAGE CALIBRATOR. Quare Associates. Bulletin, 4 pp. Gives details about an ac plug-in instrument whose output can be used as a standard. Its accuracy of 0.01 per cent applies to the set voltage, not to the full range. Two transformers that increase this range described, too.

(127) WIRE-WOUND RESISTORS. International Resistance Co. Bulletin C-1a, 12 pp. Two types, tubular and flat, are examined from the viewpoints of ratings (5-225 watts), resistance (0.10 ohms-0.465 megohms), and construction, coating, insulation, windings, and endings and leads.

(128) OXYGEN RECORDER. The Hays Corp. Bulletin 55-829-56, 16 pp. Describes an instrument that magnetically measures oxygen content of gases and records its findings. It's factory calibrated for plus or minus 0.1 per cent accuracy and guaranteed not to dip below 0.25 per cent.

(129) NYLON TUBE FITTINGS. Jaco Manufacturing. Bulletin, 4 pp. Treats a du Pont product called Zytel from such angles as temperature range (minus 70 to plus 295 deg F), pressure (to 500 psi), imperviousness, (to most acids and alkalies), etc. It's guaranteed not to crack under normal use.

(130) SILICON RECTIFIER. Transitron Electronic Corp. Bulletin TE-1337. Six of these units together weigh less than 10 oz and put out up to 200 amp, says the literature. They're rated up to 35 amp forward current at 125 deg C in the case.

(131) GEARMOTORS. Reliance Electric & Engineering Co. Bulletin E-2408, 8 pp. Treats varieties of three models (single, double, and triple reduction) from such points as: types (six), service (three classes), output speeds (7.75-780 hp).



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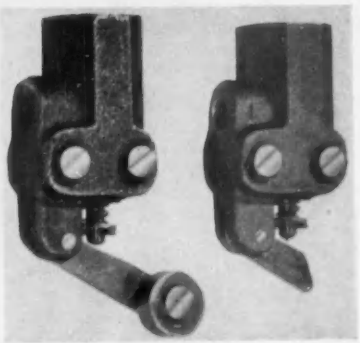
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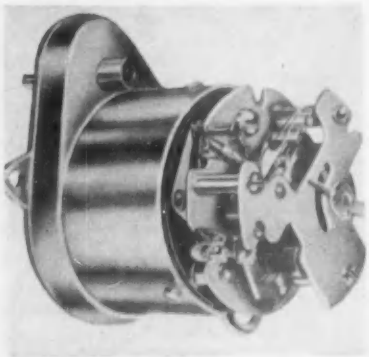
GAGE SAVER: A compact little aircraft-sized valve for protecting instruments in hydraulic or pneumatic lines **shuts off flow at pressures from 50 to to 5,000 psi,** tolerating a maximum of 10,000 psi.—The Fisher Controls Co., 1222 Seventh St., Santa Monica, Calif.

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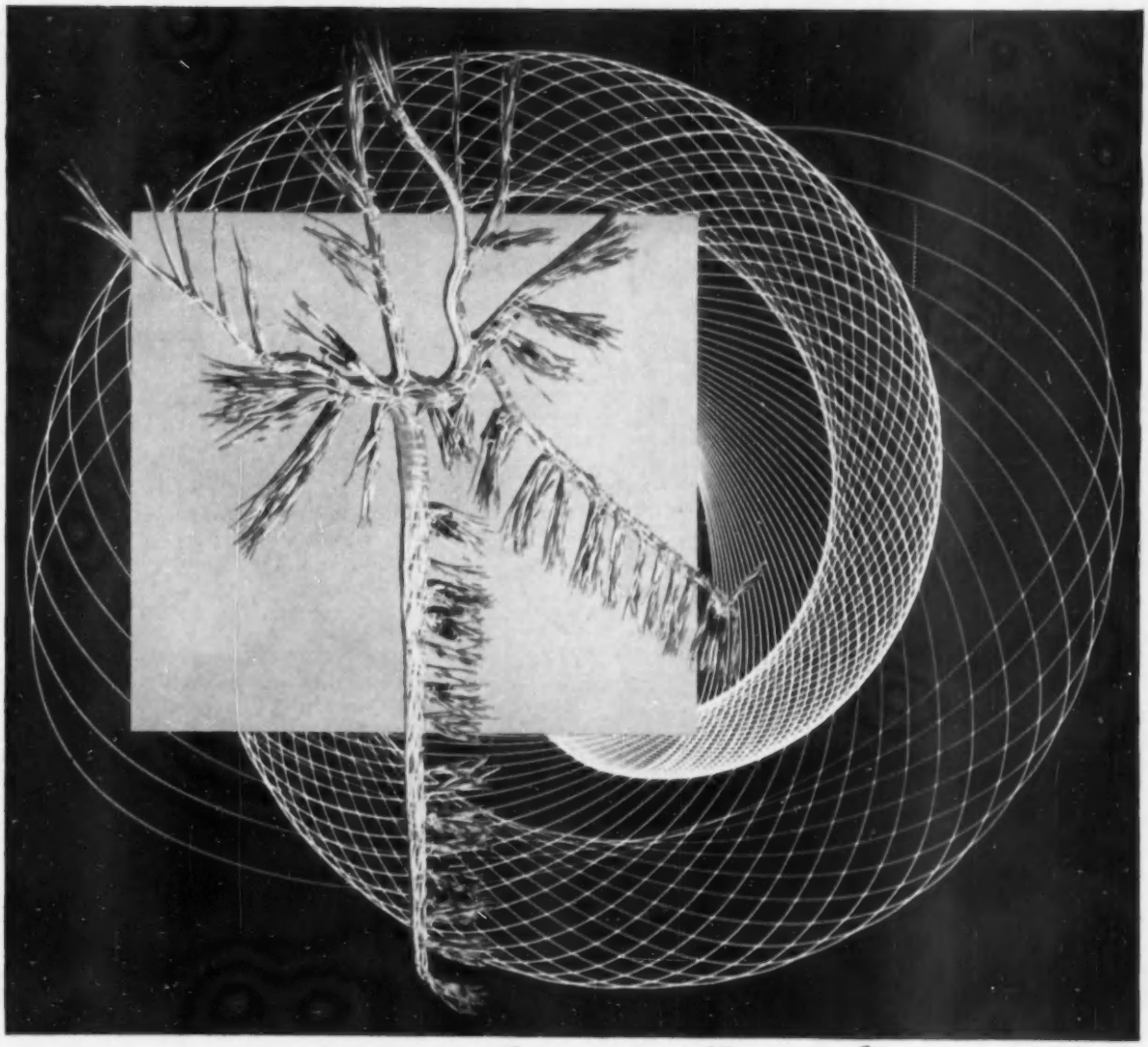
BLAST VALVE: Seen here is a rugged little valve designed to deliver a **blast of air for clearing** chips, dust, and shavings from machine tools when its lever is tripped.—W. I. Martin & Co., 224 S. Michigan Ave., Chicago 4, Ill.

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$$\bar{R}\,(T+t) = \bar{R}\,(t) + \dot{\bar{R}}\,(t)T + \ddot{\bar{R}}\,(t)\frac{T^2}{2} + \cdots$$

$$= \tilde{\bar{R}}\,(t) + \int_{-\infty}^{t} \bar{\bar{\omega}}\,(\tau) \cdot \bar{R}\,(t-\tau)\,d\tau$$

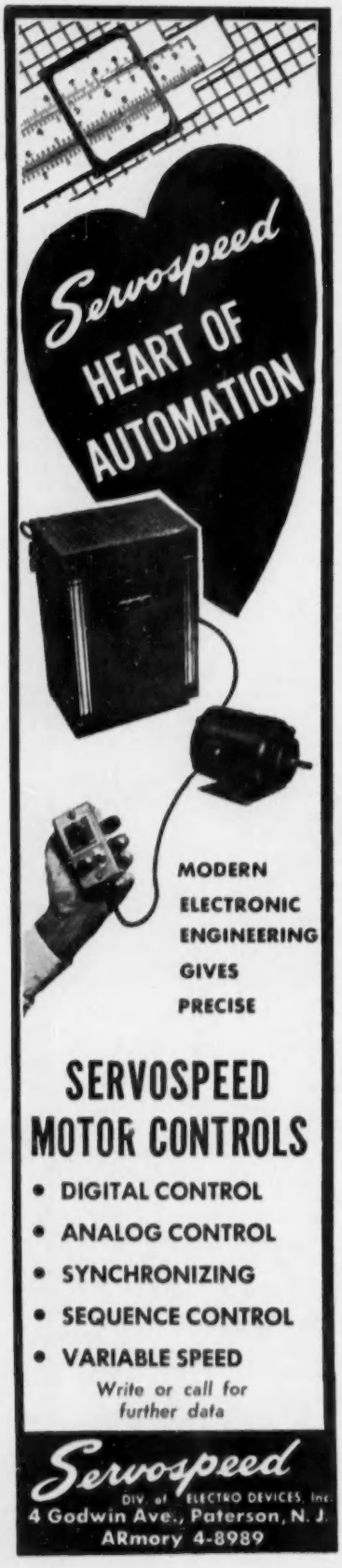
The vector equation above is basic to the development of armament controls for high-speed aircraft. A solution to this equation determines predicted target positions. Allied with this solution is the problem of optimum filtering of input data to assure the best overall system performance.

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WHAT'S NEW ABSTRACTS

Phototransistor Properties

From "Junction Phototransistors", by J. N. Shive and P. Zuk, Bell Telephone Laboratories, an article in "Bell Laboratories Record", December 1955.

The IN85 photoelectric cell described is nominally a photoconductive device. Because its structure includes a *p-n* junction, however, it can be used alternatively as a photovoltaic generator. Its active element consists simply of a *p-n* junction bar with contacts to the ends of the *p* and *n* sections. Figure 1 shows a diagram of this basic element.

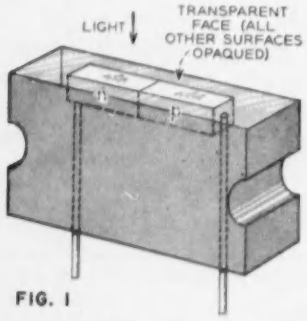


FIG. 1

In operation, a voltage bias is imposed between these terminals, with the *p* end negative and the *n* end positive. With this polarity, the junction becomes simply a reverse-biased diode with very high impedance to current flow in the dark. When light falls on or near the junction, the junction impedance is reduced and an increased current flow, of magnitude approximately proportional to the incident light flux, results. This increased current then can be used to operate a sensitive relay or to give a reading on a meter. The design and fabrication of a phototransistor is described.

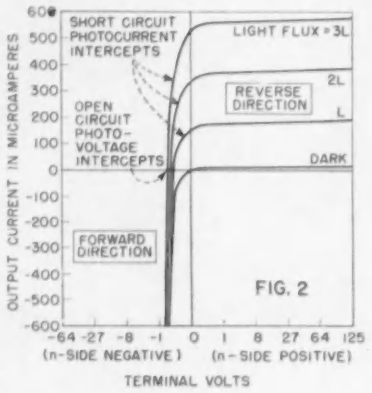


FIG. 2

The IN85 phototransistor has the current voltage characteristics shown in Figure 2. Note that for applied voltages in the range above plus 1 volt the response is practically linear, in that equal increments of light flux result in equal increments of output current. This linearity is important if one is considering, for example, the high fidelity reproduction of light signals.

Other interesting properties of the IN85 can be seen from the curves of Figure 2. If the lead wires are short-circuited so that no terminal voltage can appear, a short-circuit current will flow for each level of illumination. This current will have a magnitude almost as great as if the unit were biased several volts in the reverse bias direction. Observe also that if the phototransistor is left open-circuited so that no current can flow, an emf develops between the terminals when the cell is illuminated. This emf biases the unit in the forward direction, and the magnitude of the emf is the

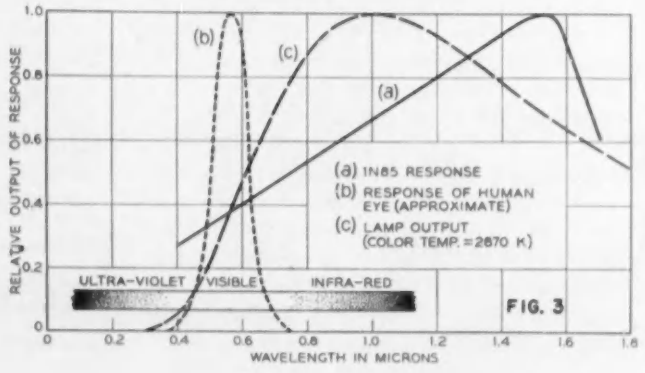
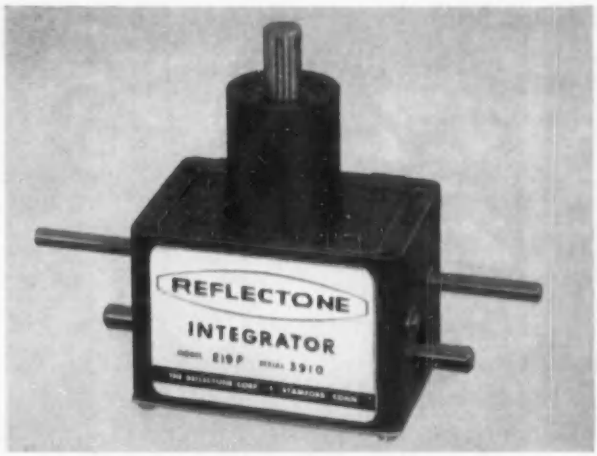


FIG. 3

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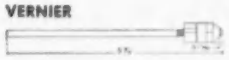
SPEED Input can be any value from 0 to 750 rpm. Output will be controllable up to over twice the input.

TORQUE Input (no load) requires 5 ounce-inches maximum. Output provides 4 ounce-inches maximum.

LUBRICATION Not required.

CONTROL ROD VARIATIONS

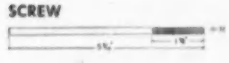
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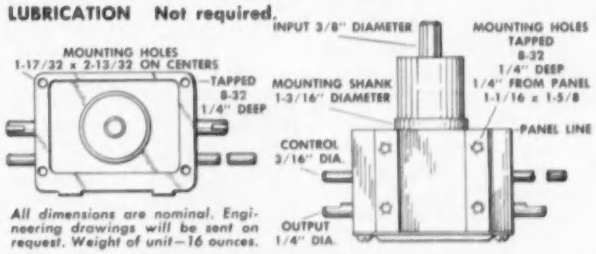


SCREW



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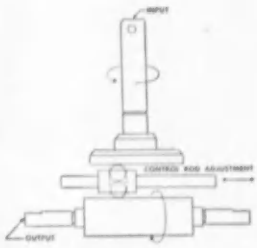




All dimensions are nominal. Engineering drawings will be sent on request. Weight of unit—16 ounces.

Two standard housings available; *Universal* (Model 219) and *Panel* (Model 244). Special control rods can be designed to customer specifications; location of control rod can be specified.

WRITE FOR COMPLETE DETAILS, OR SEND BRIEF OUTLINE OF YOUR APPLICATIONS OR REQUIREMENTS.



OPERATION

The rotation of the input shaft and disc drives the balls by friction, and these in turn drive the roller and output shaft. Since the balls merely act as idlers, and the roller diameter is uniform, the radius at which the balls are located on the disc determines the actual speed ratio between the output and input. This linear relationship, which can be expressed as

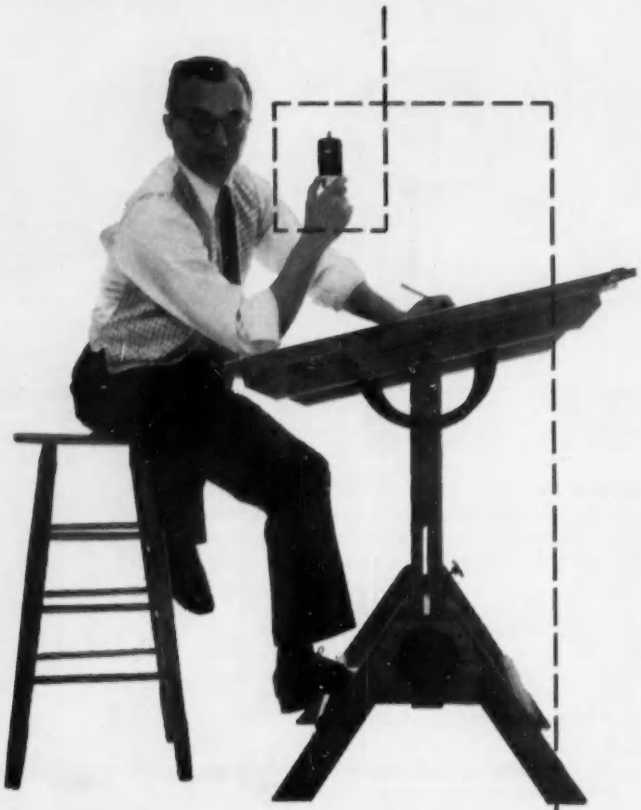
$$\frac{\text{output}}{\text{input}} = \text{control rod position} \times \text{multiplier}$$

permits the unit to be used in a wide variety of instruments such as variable speed drives, integrators, multipliers, and mechanical servos.

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ABSTRACTS

open-circuit voltage of the device when used as a photovoltaic cell. The highest voltage that can thus be developed is around half a volt per cell for germanium. The Bell solar battery, which employs silicon, has a somewhat higher open-circuit photovoltage.

As for all photoelectric devices, the response of the IN85 depends upon the wave length of the light to which it is exposed. Figure 3 shows that the IN85 encompasses the entire range of the human eye as well as most of the range of radiation from a high-temperature projection lamp.

The output response of the IN85 depends not only on the intensity and wave length of the input light, but also on where the light is incident upon the germanium bar with relation to the junction. If a small spot of light is focused on the surface of the bar and is moved from one end of the bar to the other, the output current will vary with the position of the light spot, as shown in Figure 4. The response is highest when the light is incident exactly on the junction, and falls off as the light spot is moved away from the junction in either direction.

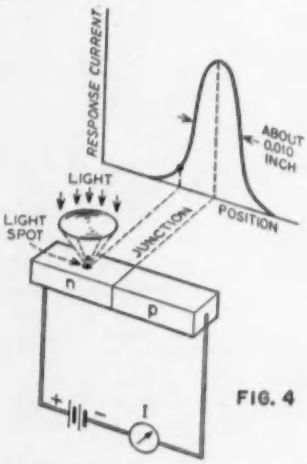


FIG. 4

The speed of the response of the IN85 depends similarly on how far away from the junction the light is allowed to fall. If the light is incident exactly on the junction line and nowhere else, the speed of the response should be more rapid than the best measuring technique can resolve. For light falling farther away from the junction, the response is more sluggish. In high-speed switching applications or high-frequency signal transmission applications, it is therefore necessary to mask the window surface of the photocell so that light can fall only in a restricted region at, and very

near, the junction. In actual tests performed to determine practical masking slit widths, it is found that response times of about ½ microsec can be achieved with a masking slit 0.007 in. wide, centered over the junction line. The physics of these spatial-response and time-response effects are described in the article.

On Air Components

From "Points to Consider in Selecting Hydraulic System Components" by W. T. Stephens, Cleveland Hydraulics Co. "Machine Design", Feb. 23, 1956.

As the title of this eight-page article indicates, the author has considered the salient points in selecting such hydraulic components as cylinders, motors, pumps, valves, connecting lines, reservoirs, and accumulators. Succinct descriptions of each component are given without going into mathematical analyses of the components or the system. The discussion adequately handles the basic purpose in the hydraulic system of each component, and the ramifications of various designs.

Thus, the article covers the relative merits and applications of long-stroke and short-stroke cylinders, illustrates methods for using cables or chains and sheaves to multiply cylinder stroke, and discusses such pumps as gear, vane (constant- and variable-delivery), and piston (constant- and variable-delivery) types. Typical operating conditions, such as pressure and speed, are discussed for each pump design.

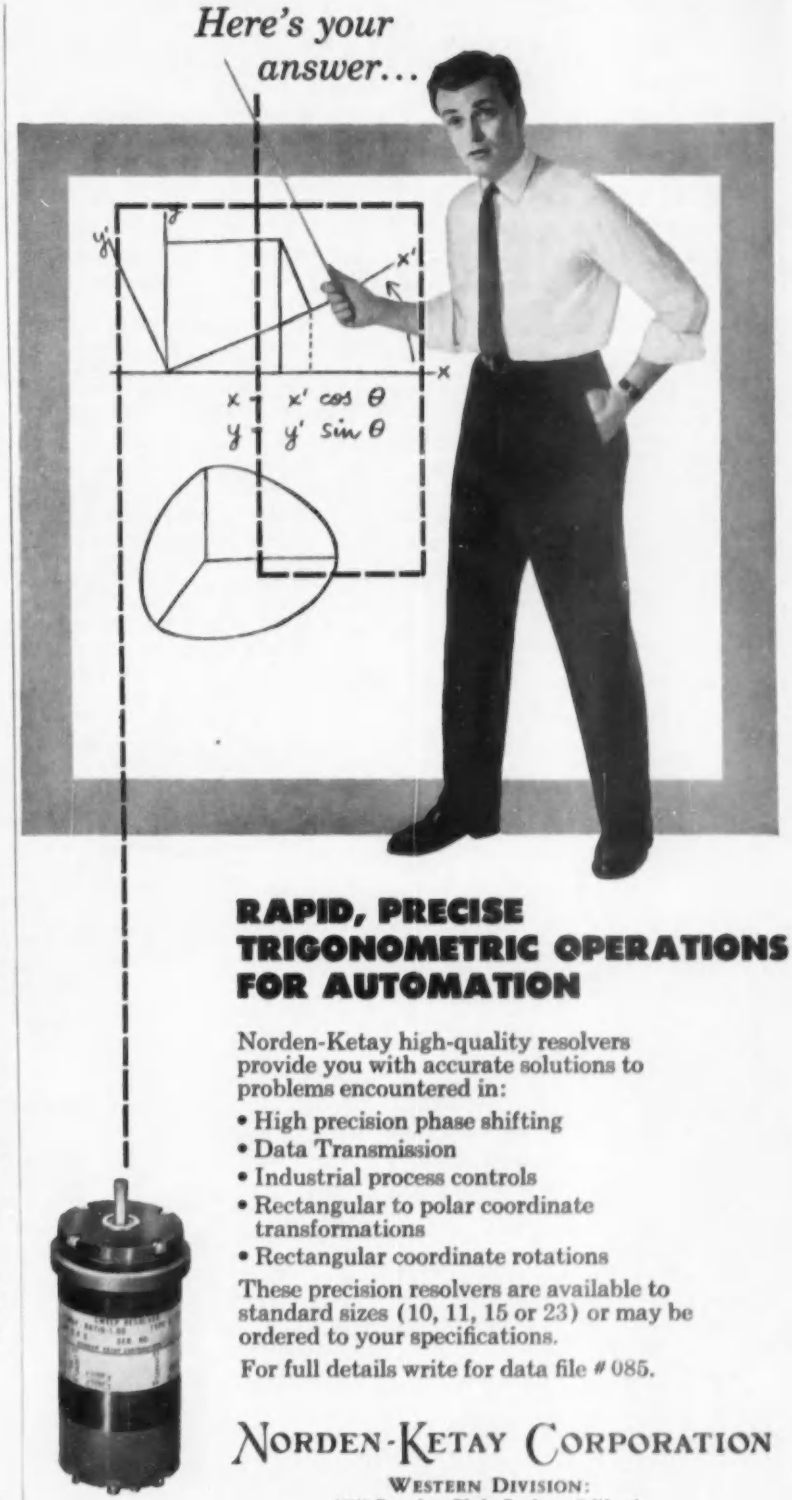
There also are comments on and brief descriptions of the many valves available for hydraulic systems. Included in this section are full-series multiple, series-parallel, parallel, relief, sequence, unloading, and solenoid valves.

The author illustrates and discusses recommended designs for reservoirs and accumulators, and points out practical considerations for oil lines and oil viscosity. Two tables serve as useful check lists in selecting cylinders, motors, and pumps.

Controlling a Reactor

From "Automatic Period Control of the Raleigh Research Reactor" by Harold A. Lamonds, North Carolina State College. "Nucleonics", March 1956.

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tronic period-control circuit on the reactor at Raleigh, the power level was changed by switching the power-level control system from automatic to manual. Then the operator manually positioned the control rod to assure a safe period during the change-over to the desired power level. This dual control of the reactor, using both manual rod positioning for period control and automatic power-level control, had two drawbacks: either the transition time was too long or the rod overshot for a time—perhaps to a near-dangerous condition.

Adding an automatic period control to the already-present automatic power-level control results in a completely automatic reactor control system that allows fast, but safe, transition to a new power level.

The period controller contains an *R-C* differentiating circuit whose output is summed with the level-error signal in the rod's servo-controller. "To achieve a change in power level automatically at a constant period, a signal proportional to the period or to some simple function of it must be fed into the servo system. Since the period is infinite for constant-level operation, it is not feasible to use a proportional signal. An inverse-period signal, on the other hand, provides the needed qualities to tie in simply with the existing level control. That is, the signal is zero for steady-state operation and increases with decreasing period."

Figure 1 details the electronic circuit used to obtain the inverse-period signal. The circuit contains a switching arrangement that allows the operator to preselect one of several periods. Representative improvement in the reactor's transient response to sudden changes in power-level demand are seen by comparing Figures 2 and 3 (the automatic period control operative and inoperative).

Apparently this new control circuit serves its purpose well, for the author makes this final comment: "The simplicity and speed with which power-level changes can be made with complete safety further reduce the need for dependence on human judgment for safe operation of the reactor."

Fig. 1

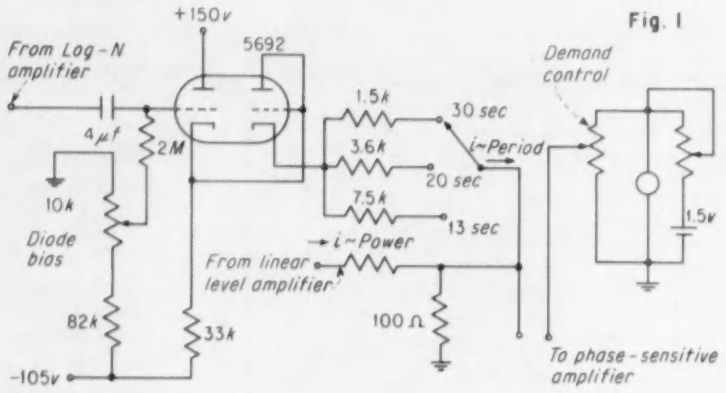


Fig. 2

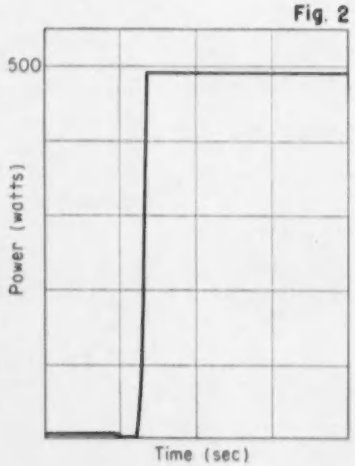
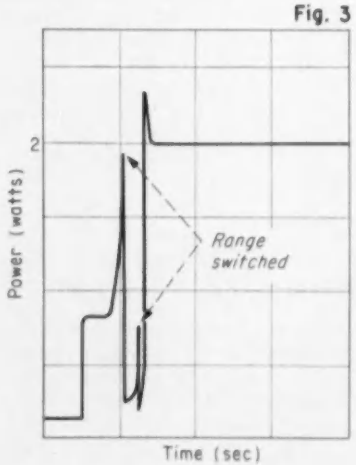


Fig. 3



electronic "brains" for industrial control

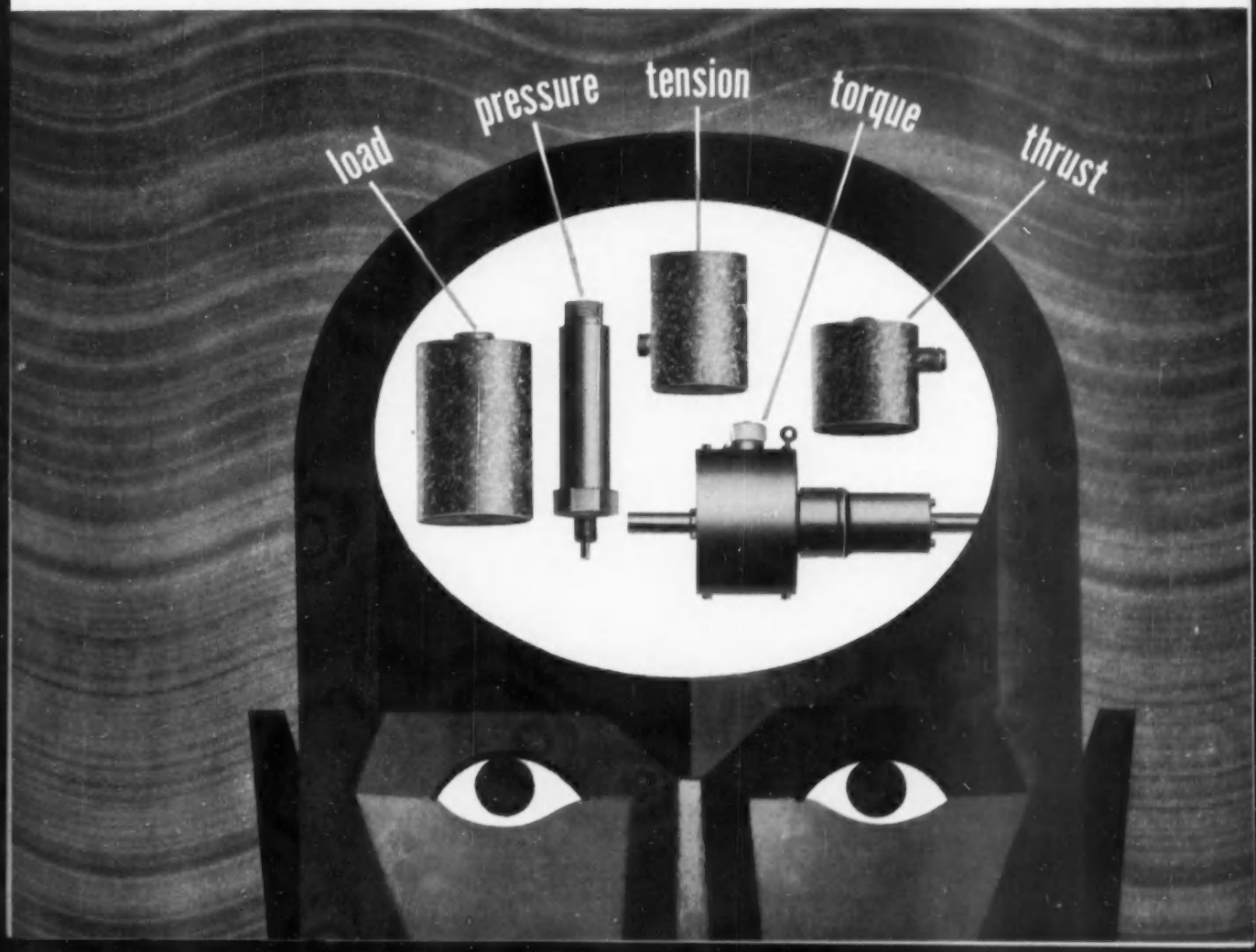
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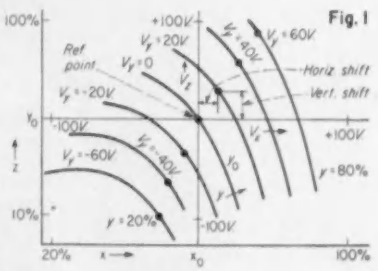
Nonlinear Simulation

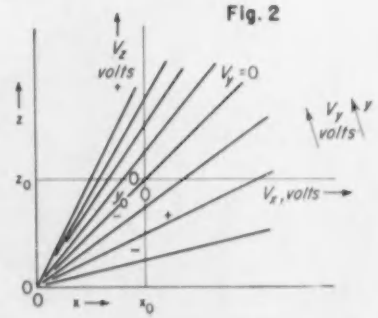
From "Representation of Nonlinear Functions of Two Input Variables" by D. A. Elliott, Curtiss-Wright Corp. ASME 56-IRD-11

This paper discusses in clear terms the author's technique for producing nonlinear functions of two input variables with standard analog equipment. The method depends upon a regular progression among the lines in a family of curves to be simulated on the computer. Most functions have such a progression; this was the case in the problem solved by the author—simulation of several types of ramjet and turbojet engines.

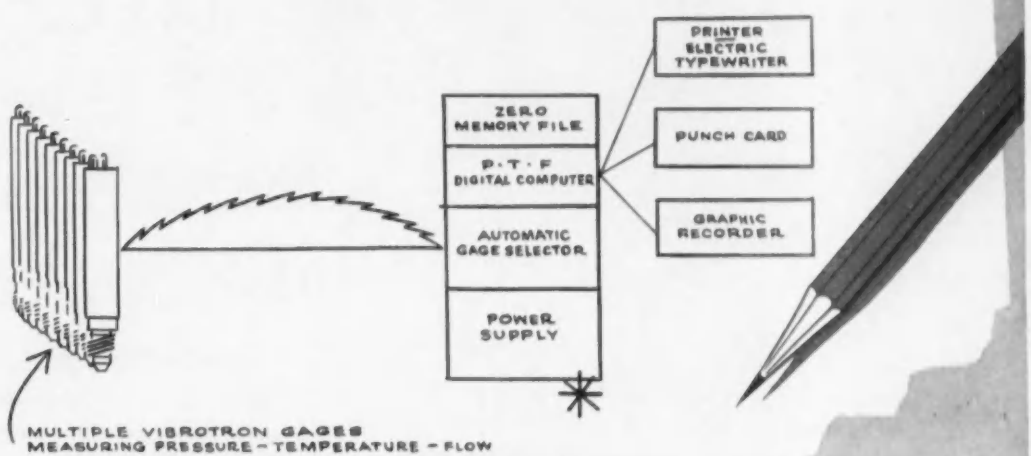
In general, this regular progression appears to be either a translation or shifting of curves (Figure 1), or a rotation or fanning out of curves (Figure 2). The author deals in his paper with both types of three-dimensional plots and shows how to determine the shifting functions, set up the block diagram for the operation, and then convert this information to analog equipment interconnections that simulate the three-dimensional relationship. Here, briefly, is the way translated curves can be simulated by the technique:

Consider Figure 1. A reference point is selected near the center of the family of curves so that all variables have zero voltage at this point. "A transparent overlay having a single

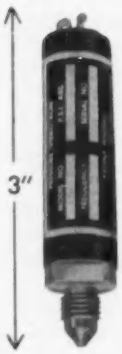




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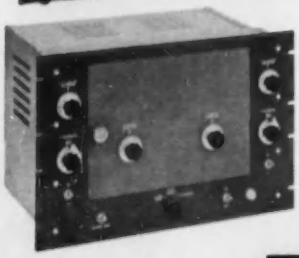
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ABSTRACTS

basic curve is plotted so that by successive shifts it can be made to match each curve of the family . . . to determine the shifting functions, the reference point is marked on the basic curve of the overlay. As this curve is shifted to each line of the family of curves, the point to which the reference point has moved is marked on each line. These points define the required amount of vertical and horizontal shift." If f_1 is the basic curve, the author points out that "the amount of horizontal shift may be plotted as a variation of input v_x for each increment of v_y to form f_2; and similarly, the vertical shift f_3 is plotted as the variation of v_x corresponding to each increment of v_y." These shifting curves, usually not elaborate, require only simple limiter or diode circuits for their simulation, and are shown in Figure 3.

Fig. 3

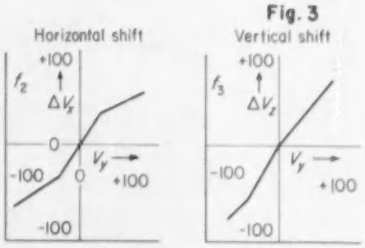


Fig. 4

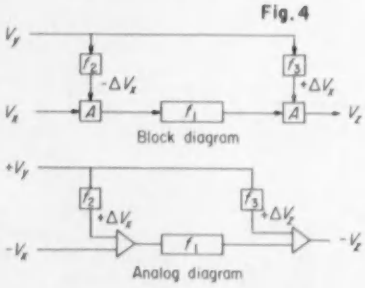


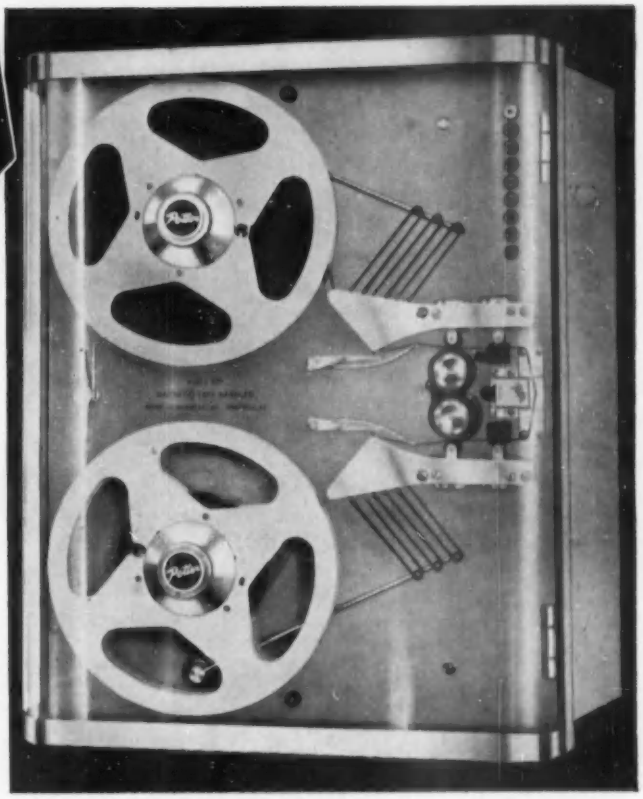
Figure 4 shows the block and analog connections needed to obtain combined horizontal and vertical translation. It can be seen here that v_z depends on the summation of the basic nonlinear curve f_1 and the two shifting relationships f_2 and f_3.

The author also treats in detail three-dimensional curves that fan out to form the family of curves. Here the shifting functions depend on the tangents of the curves and the analog simulation involves multiplication, rather than summation.

The author claims that in applying this method to problems in simulating engines he realized an accuracy of about ½ per cent in the working

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range and about two per cent at the limits of the range.

The technique can be extended to functions of three input variables, but then the amount of equipment required and the complexity of the problem increase.

Solution by Nomograph

From "Rectangular Nomographs—Four Sides to an Equation" by W. E. Powell, Ford Motor Co. "Product Engineering", March 1956.

This article shows in detail the construction of rectangular nomographs for the solution of four-variable equations of forms such as $S = Mc/I$ (blending stress), $PV = RT$ (law of gases), $\theta = TL/E_sJ$ (angle of twist), etc.

"Rectangular nomographs," the author says, "are proportional-type alignment charts in which one scale is arranged along each of the sides of a rectangle. Each scale corresponds to one variable of the equation. Perpendicular intersecting lines are traced on a transparent overlay, and this overlay is placed over the nomograph. When three of these perpendicular legs are aligned with known or assumed values, the fourth leg is automatically positioned over a value which completes a solution of the equation." Once the nomograph is set up, the equation is solved quickly, easily, and accurately, thus allowing less skilled assistants to aid in the solutions of the equation.

As an example, the author constructs the nomograph of the equation

$$S = \frac{X^{3/2}}{3Z^2}\,Y^2$$

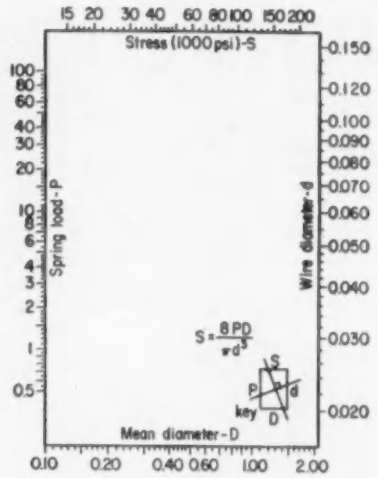
or $\frac{S}{X^{3/2}} = \frac{1}{3}\,\frac{Y^2}{Z^2}$ (proportional form)

by following seven detailed steps.

These steps are:

- ▶ arrange equation in proportional form
- ▶ draw rectangle and assign scales
- ▶ determine scale direction
- ▶ determine relative length of scales
- ▶ find actual length of scales
- ▶ construct scales, and
- ▶ align scales

Since these four-variable equations involve multiplication, division, and raising to a power, the nomograph uses logarithmic scales. Hence, the author includes a template for the construction of these scales over a



ten-to-one range of variable for any necessary distance on each side of the rectangle. Thus, finding the relative scale length merely requires adapting a distance for each variable and multiplying the distance by the variable's exponent. If the resulting scale distances are unsatisfactory for actual construction on the chart, then all relative scale lengths are multiplied by the same factor to obtain the actual scale lengths.

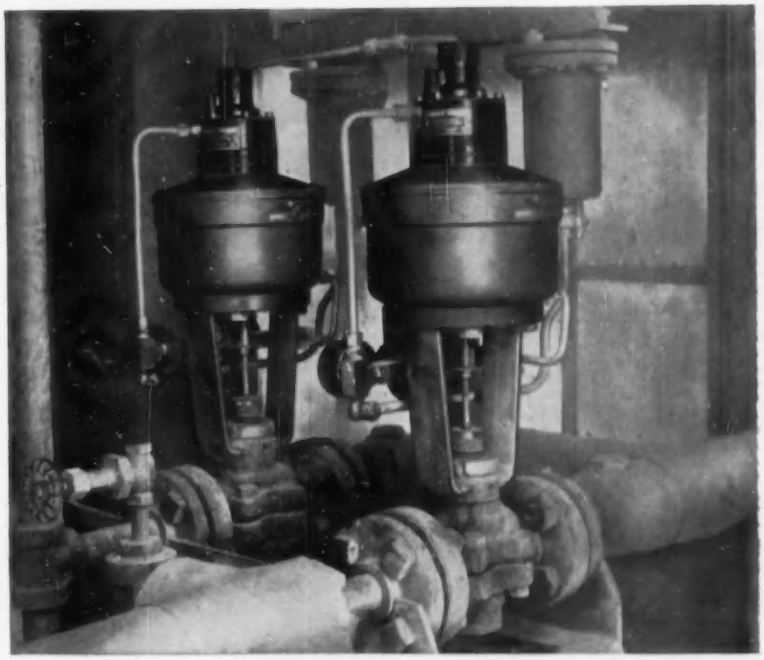
The figure reproduced here shows the completed nomograph for computation of stress in round-wire helical springs. This chart solves the relationship:

$$S = \frac{8PD}{\pi d^3}$$

Briefly Noted

THE MAGNETIC PARTICLE CLUTCH AND ITS APPLICATION TO SERVOMECHANISMS *by W. P. Jones, Naval Research Laboratory. November 1955. 24 pages. (Order PB 111782 from OTS, U. S. Dept. of Commerce, Washington 25, price 75 cents).*

In a unique application of clutches as the prime mover in a servomechanism, it was found that the clutch shows advantages over a servomotor of comparable rating because the control power for a given output power is relatively small compared with the power required in the control phase of the servomotor. The torque is linear with control current, the torque-to-inertia ratio is higher, and the time of response can be made shorter. When low-inertia outputs are desired, the clutch should have a thin-walled cylinder output with external coil structure.



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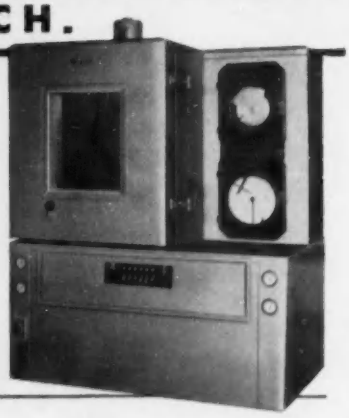
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ELECTRONICS, WAVES AND MESSAGES. *John R. Pierce, Director of Research, Electrical Communications, Bell Telephone Laboratories, 5½ by 8 in., 318 pp. Published by Hanover House, Garden City, New York.* $5.00.

At long last, here's a book about electronics that can be understood. Its author, a highly respected scientist in the field of communications, recently retired as editor of the *Proceedings of the Institute of Radio Engineers*. His background, as a scientist and as a writer, eminently qualifies him to author a book such as this.

Dr. Pierce has succeeded remarkably in unveiling the mysteries of electronics to the layman, stating in plain English the physical facts and theories about his subjects and for the most part avoiding the mathematical shorthand of the engineer and physicist. The technically trained man will be amazed to find, however, that he sacrifices none of the rigorous theoretical and practical limitations of the art in so doing. He has painted a word-picture of great faithfulness, with a clarity and simplicity achievable only by a trained writer who knows his subject completely.

Though his main topic is communications, Dr. Pierce ranges widely into the related fields of physics and communication theory, of relativity and quantum mechanics, to deepen the reader's understanding of the behavior of electrons and waves in communications devices. In his introductory chapter he reviews for the nonexpert reader the little mathematics that he later makes use of in the text, and then goes on to Newton's laws of motion (complemented in the light of relativity in a near-final chapter), electric fields, magnetic fields, and waves.

Dr. Pierce spends an entire chapter discussing what he calls "Maxwell's wonderful equations". These equations are fundamental to electronics and all of physics in describing the behavior of electric and magnetic fields. They hold true even in the light of modern relativity and wave and quantum mechanics. As in all his discussions, he ferrets out and displays clearly much of the meaning and implication in this deceptively simple pair of mathematical statements. Even the electronics engineer will find that he learns much as Dr. Pierce explains first the behavoir of the complex betatron and then that of the simple ca-

pacitor by applying Maxwell's equations.

The book covers many other subjects, giving clear explanations that are completely up to the present state of the art. Some of these are: bandwidth, traveling-wave tubes, noise, radiation, picking-up television, microwaves, communication (or information) theory, relativity, and quantum mechanics. The last includes an extremely lucid view of the behavior of the transistor and other solid-state devices.

To quote Dr. Pierce, "The reaction to understanding finally achieved is sometimes 'Oh, that is simple,' with an implication that because it can be understood it can't be very important or profound. Such an attitude disregards the fact that brilliant men have failed for centuries to understand just such simple matters, and that only very brilliant men were finally able to make them clear and simple to us, the heirs to their insight." Dr. Pierce succeeds in making very difficult things clear and simple indeed.

Higgins on Automation . . .

PRINCIPLES OF MASS AND FLOW PRODUCTION. *Frank G. Woollard. 195 pp. Published for "Mechanical Handling" by Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E., 1, England. 25 shillings.*

This book provides an excellent British complement to John Diebold's *Automation: The Advent of the Automatic Factory*. But whereas Diebold wrote on business aspects of automation, Woollard delineates the engineering aspects, paying attention to how the technological developments actually can be effected by the engineer and production man.

Starting with an interesting chapter on the "History of Flow Production", the book traces the evolution of automation, placing particular emphasis on its development in the British automobile industry—where the author has spent much of his professional life.

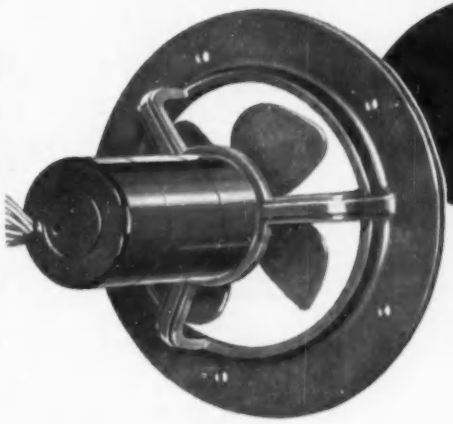
In Chapter 2, "Range of Applications", the author discusses certain supplementary broad issues, knowledge of which is pertinent to a true understanding of the subsequent detailed consideration of the principles underlying the flow-production system. Thus, the usefulness of flow methods in small-scale manufacture of very large-size units is stressed. The methods are illustrated by detailed accounts of the building of steel-compartmented passenger cars and machine tools in England, and production of heavy vehicles in Sweden.

Chapter 3, "The Principles: A Gen-

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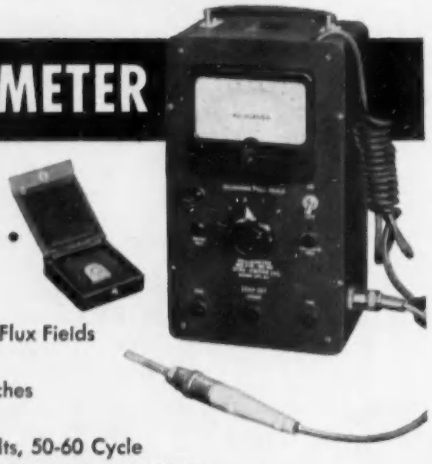
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eral Survey", offers 18 basic principles underlying flow production. A detailed account of realization and/or application of these basic principles is found in the next 11 chapters, whose content can be glimpsed by their chapter headings: "Launching a New Product"; "Specialization, Standardization, Simplification"; "Raw Material Requirements"; "Achieving Continuous Operation"; "Time Planning"; "Accuracy of Workmanship"; "Long-Term Planning"; "Maintenance"; "Transfer Machines and Automation"; "Cost-Keeping"; "Automatic Transfer Machines".

The next, and longest chapter, 15, "The Automatic Factory", considers the "possibilities and desirabilities" of actually effecting automation in the factory. The "possibilities" are largely those observed in certain factories already in operation, such as the autoframe and pipe-making plants of the A. O. Smith Corp. in the U. S. and of the car-assembly plant of the Austin Motor Co. in Britain. "Desirabilities" are handled by advancing detailed answers to eight postulated questions, such as "What are the advantages of automatism?" and "What will be the social effect of automatism?".

The closing chapter, "Human Relations", covers the past, present, and future benefits of automation and concludes that "flow production is, in fact, a logical development that has tremendous advantages and when properly employed is of benefit to the whole community", thus reaffirming the author's opinion that "provided that the human relations aspect is properly safeguarded, flow production methods can become a most powerful factor in easing the labour and promoting the well-being of mankind."

. . . on Process Control

PROCEEDINGS OF THE CONFERENCE ON AUTOMATIC CONTROL IN THE PROCESS INDUSTRIES. *Published in "The Quarterly Transactions of the Institution of Chemical Engineers" (London), Vol. 33, No. 3, 1955, pp. 155-239. Sold by the Institution of Chemical Engineers, 56 Victoria Street, London, S.W. 1, England. 12.5 shillings.*

This London conference of Oct. 4, 1955, sponsored jointly by the Institution of Chemical Engineers and the Society of Instrument Technology, was intended "to focus attention on the common interests of the chemical engineer and the process control engi-

neer, and on the necessity for their working together as closely as possible to develop this control system design."

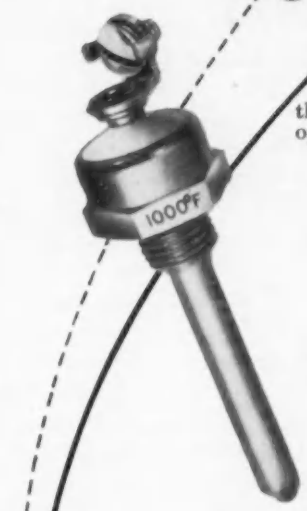
To such end, the need for more intensive study of the economics of process control and of the characteristics of the process plant were especially stressed. For the economics of process operation determine, in the large, specification of the operating performance of the control system. And in turn, the design of such system hinges on ability to ascertain (and to modify as necessary) those characteristics of the processes and plant that enter into the control scheme.

The first group of three papers includes two well-detailed works: R. S. Medlock, "Fundamentals of Automatic Process Control" and J. McMillan, "The Dynamics of Process Plant". The third paper, by B. S. Balls and A. H. Isaac, "Automatic Process Control and Chemical Engineering", focuses attention on the role of the chemical engineer in plant design and control. In particular, means of improving controllability by considering the type of reaction, type of process, and method of regulation, and the feasibility of introducing controllability at the mechanical design stage, are suggested as desirable fields of research that fall within the province of the control-oriented chemical engineer.

These papers are followed by an eight-page digest of the discussions advanced by some sixteen individuals and of the corresponding closures by the authors. The presence of process control engineers among the participants made for an interesting, pointed, and provocative comment on the values and applicability of the—to many—relatively new field of process control theory.

The first four of six papers in the second group are well-illustrated accounts of certain specific applications. B. O. Smith, "Automatic Control in the Steel Industry", considers the automatic control of open-hearth and well-reheating furnaces and touches on the problems underlying control of rolling-mills. W. A. Goldstein, "Automatic Control of Batch Processes", is largely an account of cam-operated and preset types of program controllers and continuous modification of them through automatic monitoring of the raw materials and finished products. W. A. J. Preece, "The Temperature Control of Large Storage Tanks", tells about a scheme for automatic temperature control of petroleum tanks that cut yearly steam requirements in half. N. C. Underwood, "Automatic Control in the Pulp and Paper Industry", is largely a description of applications

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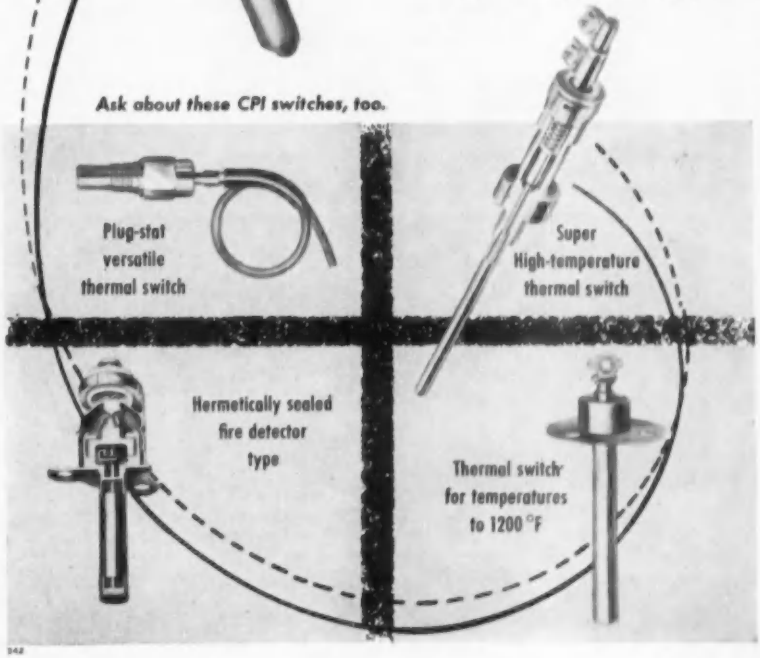


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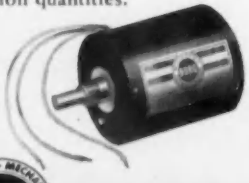
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S. W. J. Wallis, "The Economics of Process Control", is a unique discussion of the advantages of control equipment and of the effect on manpower requirements, plant-time efficiency, yield efficiency, and product control quality. An analysis of the cost of installing and operating the instrumentation for a medium-sized refining unit indicates considerable interest in the financial aspects of control practice.

In "Development of Modern Control Technique and the Pattern of Future Development", A. J. Young, one of the foremost British process control engineers, mentions some of the shortcomings of current practice and suggests developments necessary to obviate them; emphasizes the need of collaboration between maker, user, and research establishment; declares that the chemical engineer must be educated in basic principles of control theory, and urges an exchange of ideas between those who design plants and processes and those who design control equipment and control systems.

This group of papers is well-complemented by pertinent, pithy discussions by 14 contributors and by the author's closure thereto. These bring out, in particular, details of actual plant installation and the rapidity with which certain phases of modern process control theory and devices are being introduced into British industry.

A lucid resumé of the main themes and features of the conference by Sir Harold Hartley, together with concise summarizing remarks by Young, conclude the proceedings.

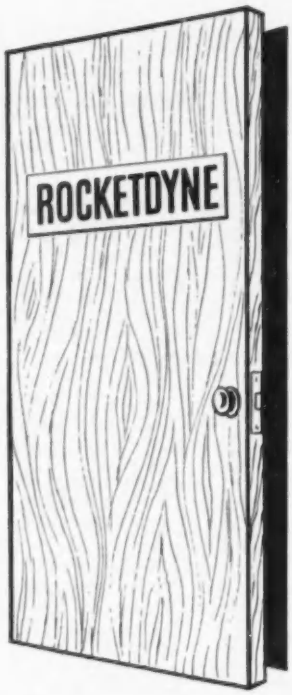
The reviewer recommends they be read seriously by all interested in process control work.

. . . on Cybernetics

LA CYBERNETIQUE: DU CERVEAU HUMAIN AUX CERVEAUX ARTIFICIELS. *(Cybernetics: From Human Brain to Artificial Brains). Paul Cossa. 98 pp. Published by Masson et Cie—Editeurs, 120 Boulevard Saint Germain, Paris VI, France. 525 francs.*

This book, by a distinguished French scientist, neurologist and physician, examines the extent to which the functions peculiar to the human brain can and—more importantly—cannot be paralleled by so-called "electronic brains" (electronic analog and digital computers).

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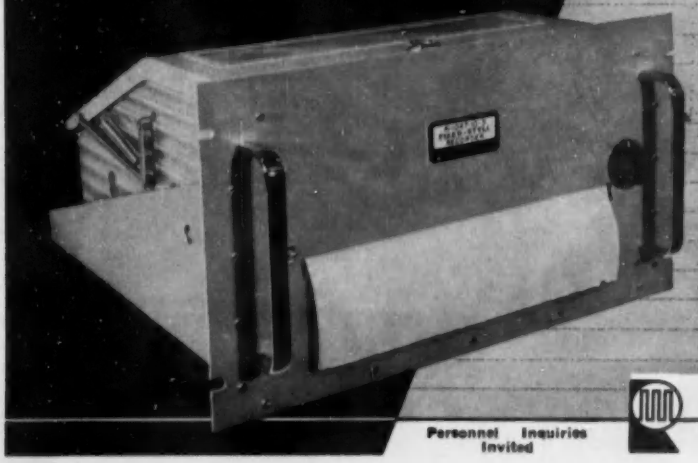
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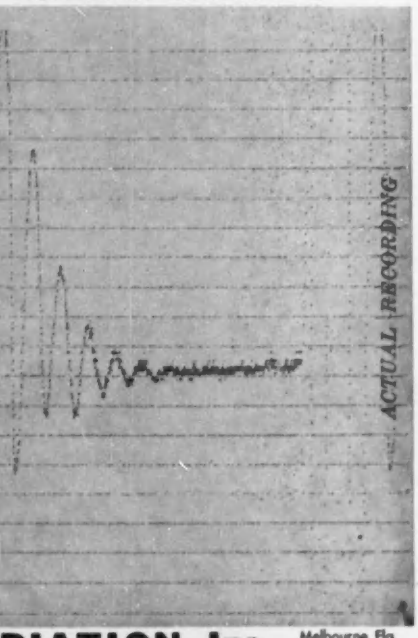
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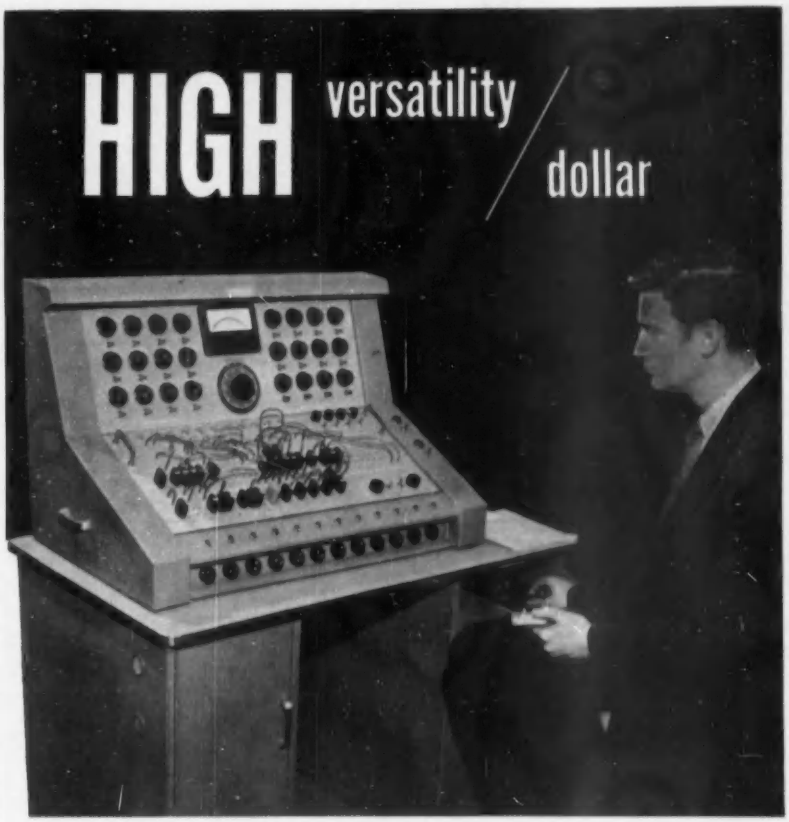
Discipline", is a concise account of the conception of cybernetics (about 1938), as rooted in the work of Wiener and Rosenbluth; of its development to date, chiefly in the United States, England and France; and of the work of some of the major contributors in these three countries.

Chapter 2, "Man and the Machine: Methods of Comparison", remarks on the shortcomings and relative merits of the two major analogical approaches to determination of the structural functioning of the human neurological system. The first, the method of comparison, entails *identification* of similar structures in man and in a suitably discerned machine; establishment thereby of corresponding functional components; and attribution of the functioning and role of a machine-member to its human counterpart. In the second, the method of models, the structure and functioning of a neurological apparatus is *conjectured*. Here the performance of an electrical or mechanical analog of the human counterpart is compared with the living original and any evidenced similarity of performance is taken as indicating correct initial conjecture as to the neurological apparatus.

Chapter 3, "The Homologies of Structure: Feedback", delineates essential action of feedback in machines, and then shows how a satisfactory explanation of certain bodily behaviors is afforded by asserting similar mechanistic actions in the human. Chapter 4, "Why the Human Heart Does Not Oscillate as a Pendulum", outlines the possibilities of occurrence of self-oscillating loops in the human neurological system.

Chapter 5, "Small Monsters", explains the actions, inherent limitations, and possible development of mechanistic devices or "animals" such as Piraux's dog, Grey Walter's tortoises, Ducrocq's foxes, and Ashby's homeostats. Chapter 6, "— and Great Monsters", outlines the origins, development to date, and functions of certain basic electronic analog and digital computers and translating machines. Chapter 7, "Problems of Information", gives a nonmathematical account of the essential connections underlying the optimum transmission of information in animate and inanimate structures.

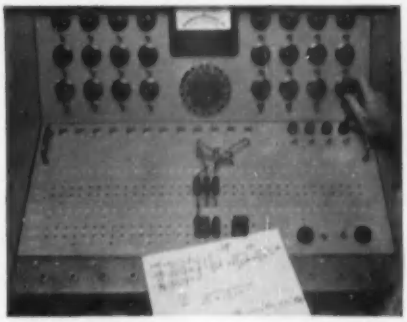
Chapter 8, "When the Creature Devours its Creator", briefly considers the economic and social consequences that might originate in an industrial revolution as the result of an uninhibited use of automatically controlled



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machines. A concluding chapter, 9, "From the Machine to the Spirit—or from the Spirit to the Machine?", discusses certain moral, spiritual, and intellectual ways in which automatic machines cannot rival the human. The author maintains machines cannot predetermine, learn, exercise a critical faculty, extrapolate from the specific to the abstract, invent, or manifest spiritual aspects. Readers whose semantics conflict with the author's will reject one or more of these premises.

. . . on Laplace Applied

DIE LAPLACE-TRANSFORMATION UND IHRE ANWENDUNG IN DER REGELUNGSTECHNIK (*The Laplace Transformation and Its Application in Control Engineering*). *Edited by R. Herschel.* 142 pp. *Published by R. Oldenbourg, Munich, Germany.* DM 12.80.

This volume comprises the proceedings of the Annual Conference of the Professional Group on Control Mathematics of the Society for Applied Mathematics and Mechanics, held at Essen, Germany, Oct. 6-8, 1954. As is customary with the group, the conference was devoted wholly to exposition and exploration of one topic—in this instance, use of the Laplace transform in modern control-system analysis.

This work is not substantially new to the control engineer who has had a good basic course in control theory. Rather, its prime value lies in the clarity of explanation of the basic theory; in the detailed numerical examples illustrating each point; and—uniquely—in showing how step-by-step buildup of the theory affords easy solution of the performance of a control system as it is made correspondingly complex. This is done by taking into account those ramifications which, though commonly neglected in simpler treatment, appreciably influence the actual performance of the system. It is mainly for this last reason that the reviewer recommends a careful reading of this excellent little volume.

Each of the eleven papers has been carefully edited, integrated, and organized by the editor, Dr. Herschel. In each case the formal presentation by the author and the discussion that followed it are made a unit.

1. The opening paper, by W. Oppelt (pp. 9-15), shows how to derive the differential equations governing the overall performance of a closed-loop system, in particular that of an

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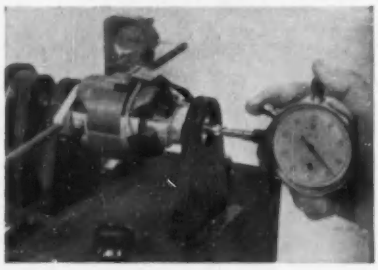
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electromechanically controlled voltage-regulated dc generator. Analysis of the structural details of the components, formulation of corresponding equations of performance, and elimination among these equations yield the desired governing equation of the output voltage.

2. G. Doetsch (16-44), gives a systematic account of that portion of basic Laplace transform theory that underlies determination of the transient performance of single- and multiple-loop control systems. Each major point of theory is illustrated by solution of a well-chosen numerical example.

3. R. Herschel (45-54) uses Doetsch's theory to determine the solutions of the governing equation formulated by Oppelt, and thus the transient behavior of the output voltage of the system.

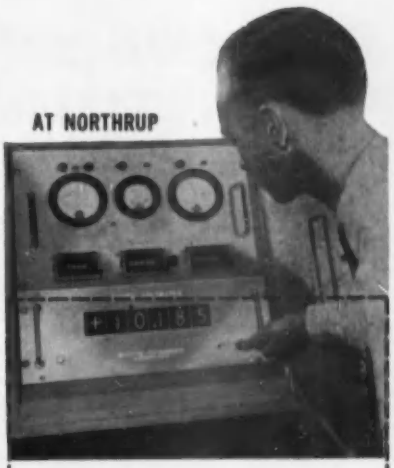
4. Oppelt obtained his governing differential equation by eliminating among the differential equations of performance of the individual components. St. Schottlaender (55-62) shows how to obtain this overall equation by transforming the individual equations of performance and then eliminating among the set of resulting algebraic equations. Effectively, this is equivalent to a use of transfer functions for the individual components.

5. In the above papers the mass of the moving iron plunger in the solenoid of the illustrative system is neglected. When this ramification is included [a study of the response as a function of the mass of this plunger is effected by J. Dörr (63-70)] a cubic characteristic equation results, with corresponding increase in the complexity of the analysis.

6. A. Leonhard (71-83), illustrates how the response of Oppelt's system to sinusoidal, repeated-rectangular-pulse, and step-function inputs can be obtained by complex-number calculation. With the basic aspect of the so-called "frequency-response" approach thus detailed, the corresponding rules for block-diagram manipulation are then formulated.

7. O. Schafer (84-89) shows how to determine the response of the system when the input function is not periodic (it was assumed periodic in the preceding papers). Further, he shows how the integral of the squared error of the output can be calculated rather simply by use of a certain convolution identity.

8. K. Kuppmüller (90-103), sets out the basic theory underlying deter-



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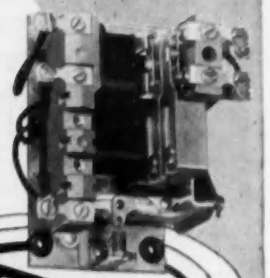
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mination of the stability of the system by use of complex loci diagrams. He applies this theory to determine system stability when dead time is encompassed in the forward link, and tells how to effect "piecewise continuous" response from the resulting transcendental overall transfer function.

9. R. C. Oldenbourg (104-114) indicates the utility of Laplace transform solution for nonlinear systems by showing how it can be used to determine response. In this case response includes an intermediate stage of control (a solenoidal component with deadband). This solution is effected by splitting the time domain into sections over which the system is essentially linear in operation.

10. H. F. Schwenhagen (115-129) advances a "physical interpretation" of the Laplace transform through consideration of the integrand as the superposition of waveforms of complex frequency.

11. The concluding paper (130-142) by J. Peters, a well-known German radio engineer, analyzes Oppelt's system by use of techniques developed for feedback-amplifier performance. In particular, the stability of the system is investigated by use of the Nyquist diagram.

. . . on Computers

[Glossary of Terms Relating to Automatic Digital Computers] *B. S. 2641: 1955. 25 pp. Published by British Standards Institution, 2 Park Street, W. 1. London, England. 3 shillings.*

The Advisory Committee for High-Speed Calculating Machines of the Dept. of Scientific and Industrial Research and the British Standards Institute produced this glossary in the belief that the development of high-speed digital computers has reached the stage where standardization of terminology is desirable.

It has roughly 100 entries referring to fundamental terms, coding systems, storage techniques, programming and pertinent routines, and a few definitions relative to number systems.

The American computing engineer will find this a handy reference when reading British literature on automatic digital computers.

Thomas J. Higgins
Professor of Electrical Engineering
University of Wisconsin

WHAT'S AHEAD MEETINGS

APRIL

American Management Association, Special Conference on Systems Planning and Control, including "Systems Role in Electronic Data Processing", $75 fee, Hotel Roosevelt, New York

Apr. 23-24

Institute of Radio Engineers, Professional Group on Circuit Theory, Symposium on Nonlinear Circuit Analysis (sessions on design, nonlinear feedback systems, discontinuous systems, random inputs, and a round-table on evaluation of methods in theory and practice), Auditorium of the Engineering Society Building, 33 West 39th St., New York

Apr. 25-27

American Institute of Electrical Engineers, Conference on Recording and Controlling Instruments, Bradford Hotel, Boston

Apr. 26-27

MAY

American Institute of Chemical Engineers, 34th National Meeting, The Roosevelt Hotel, New Orleans, La.

May 6-9

Instrument Society of America, Second National Flight Test Instrumentation Symposium. Hotel Texas, Fort Worth, Tex.

May 6-9

Western Material and Handling Conference and Equipment Show (sessions on data processing and automatic warehousing, mass movement of people, missile handling, etc.) Great Western Livestock Exhibit Bldg., Los Angeles

May 9-11

Institute of Radio Engineers, National Conference on Aeronautical Electronics, 70 exhibits, Hotel Biltmore, Dayton, Ohio

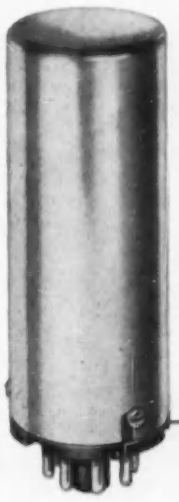
May 14-16

Symposium on Reliable Applications of Electron Tubes, RETMA Engineering Department, IRE Professional Group on Electronic Devices and JETEC, University of Pennsylvania, Philadelphia, Pa.

May 22-23

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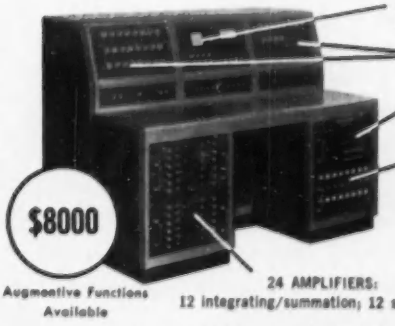
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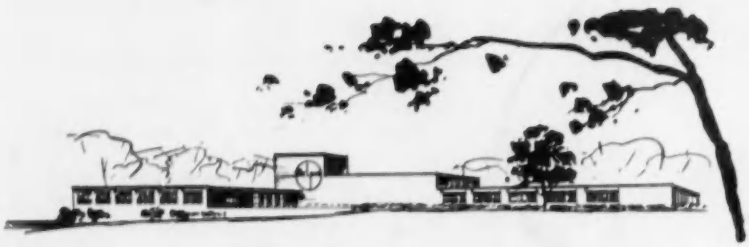
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WHAT'S AHEAD: MEETINGS

American Society for Testing Materials, Fourth Conference on Mass Spectrometry, Netherlands Plaza Hotel, Cincinnati, Ohio

May 27

JUNE

American Society of Mechanical Engineers, Semi-Annual meeting, Statler Hotel, Cleveland, Ohio

June 17-21

Stanford Research Institute and the University of California, Symposium on "High Temperature—a Tool for the Future" (methods, materials, and processes for high temperatures), University of California, Berkeley

June 25-27

American Institute of Electrical Engineers, Summer and Pacific General Meetings, San Francisco

June 25-29

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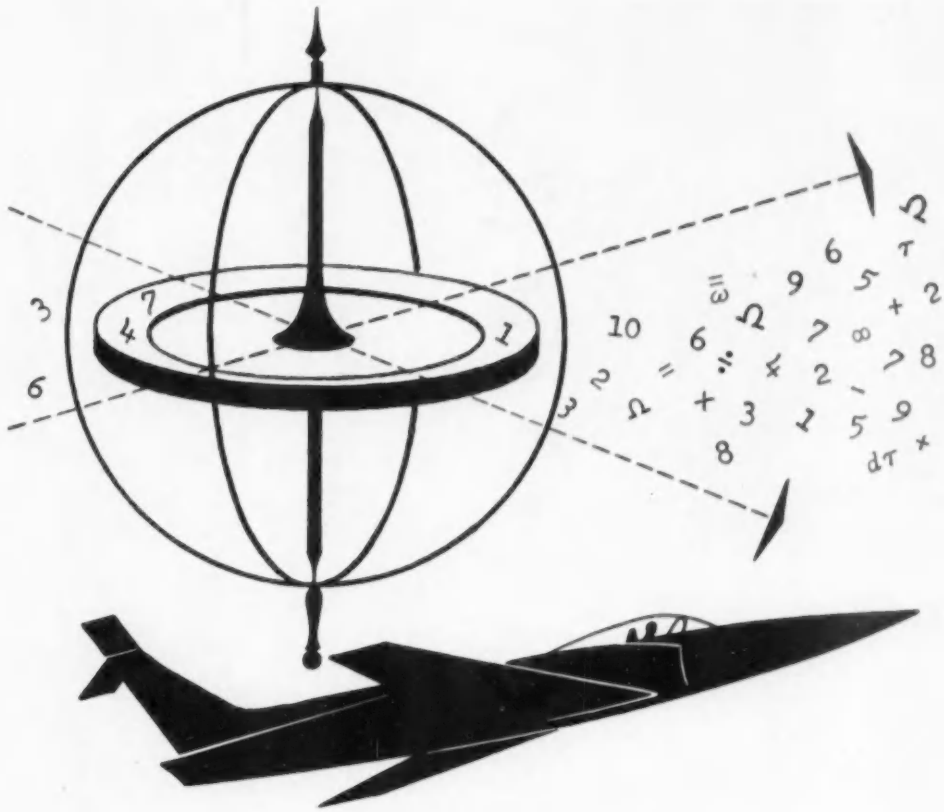
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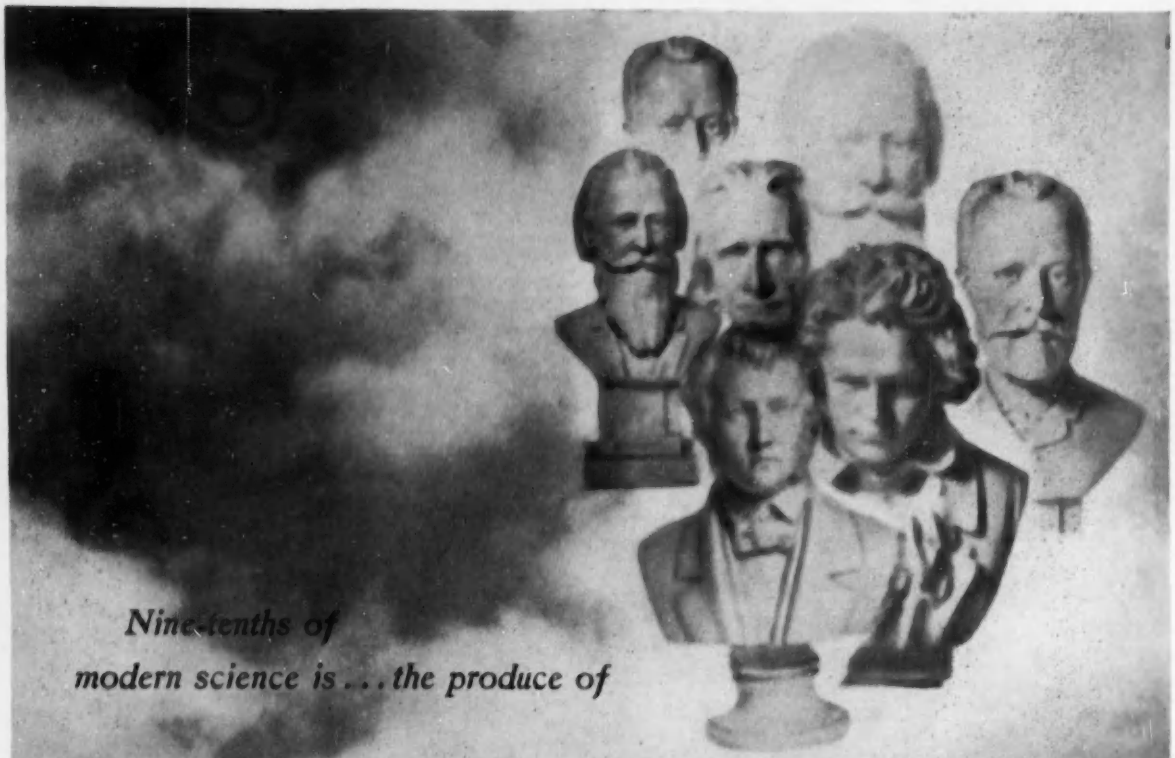
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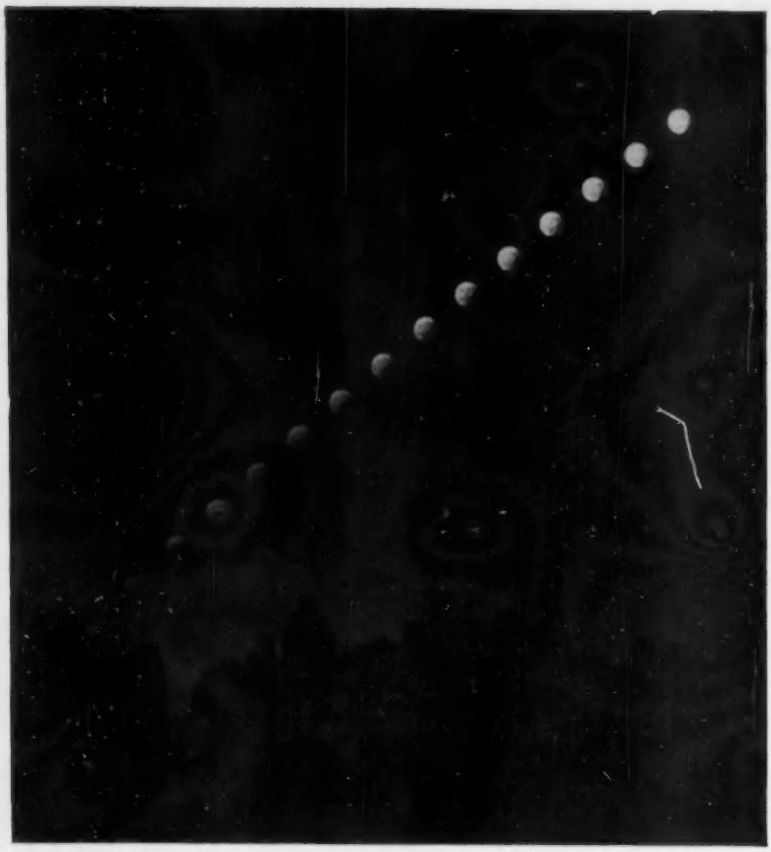
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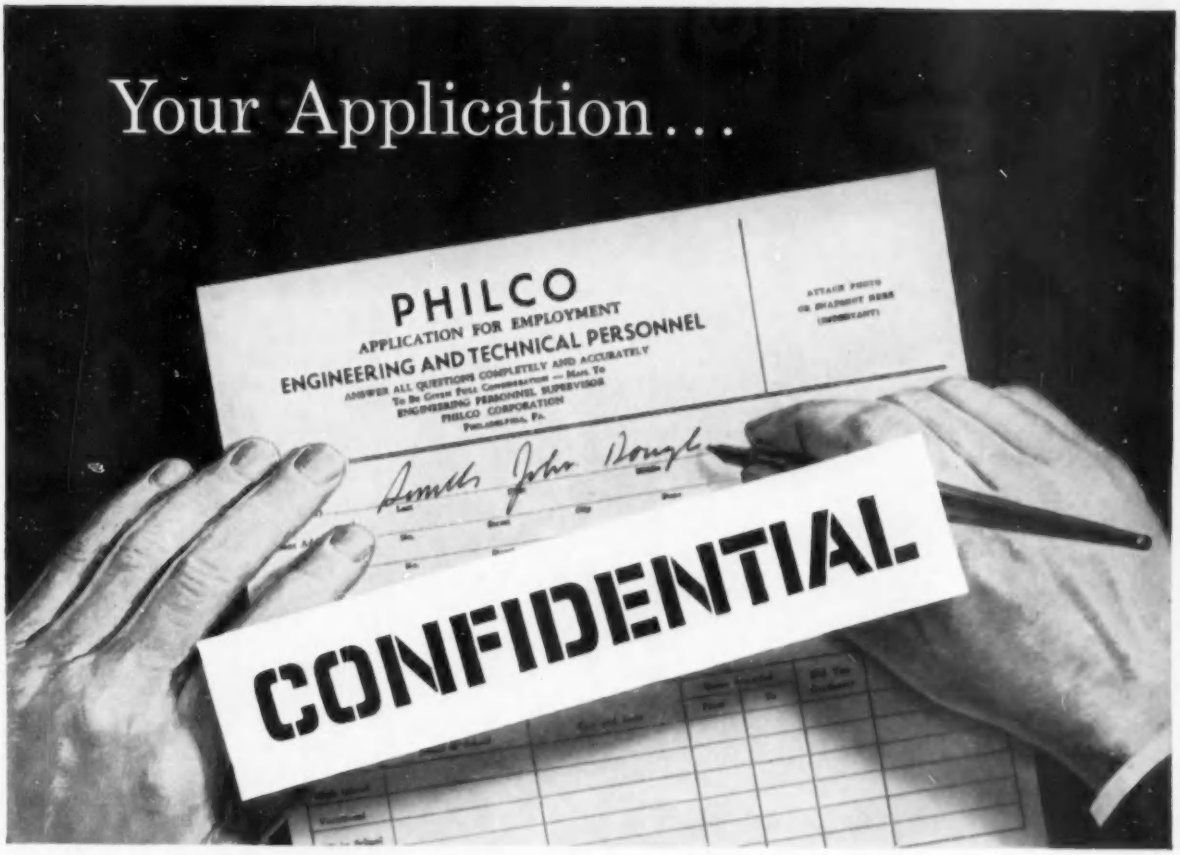
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NEW YORK, 36
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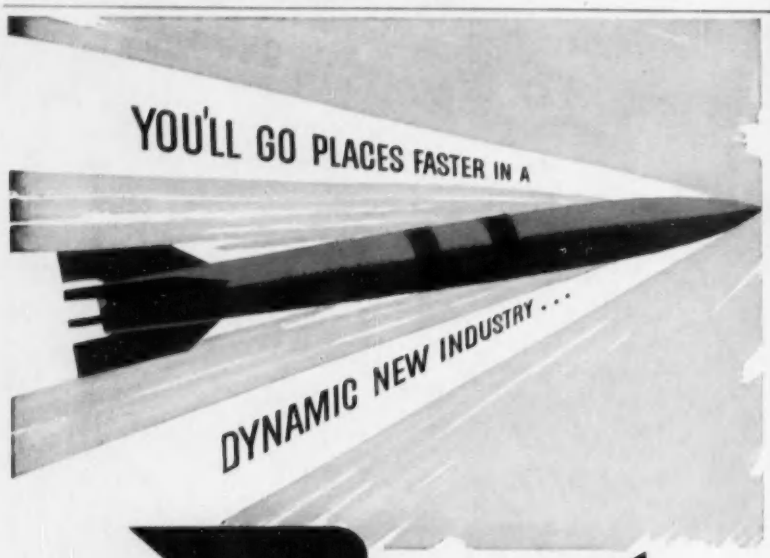
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Fort Wayne, Ind.
"America's Happiest City"

Dear Bill:

Now that Joe is on the team here at Farnsworth, he's asked me to write and give you the same story that got him interested in coming with us.

Actually, Bill, it wasn't a "story." Just a few honest-to-goodness reasons why he and Marge should make the move and let the family really live as well as let Joe grow professionally.

For instance, do you know what "sold" Marge? The fact that in living here you are only 10 minutes from everywhere—schools, churches, stores etc. and Joe goes home for lunch every day instead of week-ends. She also liked the idea of some 300 lakes within 70 miles. (Guess where they're planning to spend the summer!)

As for Joe, he's all hepped up about the work he's doing on such missiles as Bomarc, Talos, Terrier and others. Says the top-notch scientists and engineers he's working with are all big-league and he's on the team.

That's about it, Bill. An engineer with your talents shouldn't be wasting around when he can get in on the ground floor here at Farnsworth in research, development or production engineering in missile guidance and control, radar, microwaves, test equipment, countermeasures, transistor applications etc.

So—why not write, right now to Don Dionne, Farnsworth Electronics Co. Fort Wayne, Ind. (A division of International Telephone and Telegraph Corp.)

You, Joe, I and Farnsworth will be mighty glad you did.

Sincerely, Jack

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RCA . . . in New England

grows in

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RCA's aviation systems laboratory . . . at Waltham, in suburban Boston, broadens its research and development programs on electronic control systems for newest supersonic aircraft and missiles.

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Radio Corporation of America
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radar, antennas, infrared, optics.

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ARE YOU IN NEED

OF ENGINEERS
or of
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We offer a booklet especially prepared to help you solve this problem. It is called the "RESERVOIR of ENGINEERS and TECHNICAL MEN".

This booklet shows, through a listing of the major job titles held by readers of McGraw-Hill Publications, how these men are gathered in convenient, compact groups that you can economically reach with your advertising. Here are no huge, swollen circulations, with expensive price tags where maybe not one reader in a thousand would have the necessary job qualifications.

In a recent advertisement one of the leading aircraft manufacturers restated a well known, but seldom practiced principle:
A trained, experienced engineer in one specialty can be retrained in almost any other engineering specialty with a minimum of time and effort expanded.

It is one of the purposes of this booklet to show how you can best reach men specifically trained for your needs or technicians who can be easily and quickly retrained.

For your free copy of this booklet write us on your letterhead. You are under no obligation whatsoever. There is a limited supply so write us now.

McGraw-Hill
Publishing Co., Inc.

Classified
Advertising
Division

330 West 42nd St.,
New York 36, N. Y.

ADVERTISING MAN WANTED FOR TECHNICAL PRODUCTS

- Previous advertising experience not necessary but helpful. Must have at least two or three years of college with courses in engineering and technical subjects and like to write. If you have the qualification we have an opportunity open for you. Man selected will be trained in all phases of industrial advertising. In your letter of application state age, education, positions held, and give statement of why you want a career in advertising. Location: well-known Connecticut company.

P-1210 Control Engineering
330 W. 42 St., New York 36, N. Y.

project engineer electronics

Terrific opportunity
for a sharp young engineer
to take on heavy responsibility
and get paid for it.

Reply in confidence to:
P-1317, Control Engineering
330 W. 42 St., New York 36, N. Y.

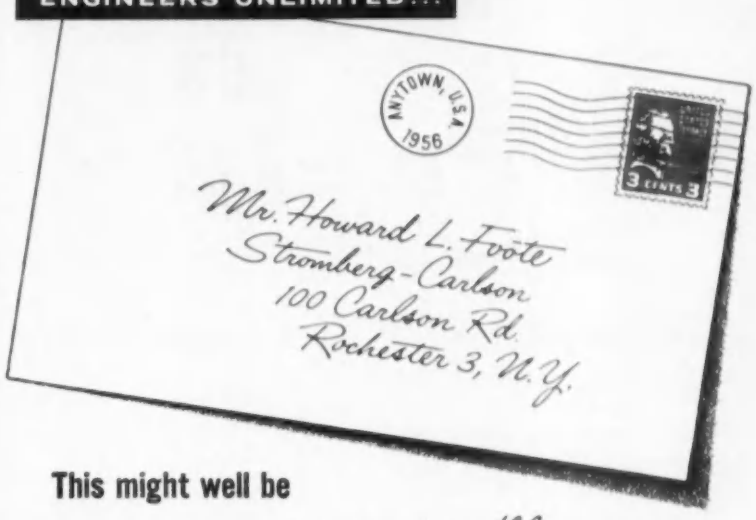
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Is it complete?
Are you expanding it?
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Naturally, you are anxious to secure the most suitable man or men available. You want men with the special training that will make them an asset to your organization. You can contact such men through an advertisement in the Employment Opportunities Section of CONTROL ENGINEERING.

Classified Advertising Division
CONTROL ENGINEERING
330 W. 42nd St., New York 36, N. Y.

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This might well be the most important letter *you'll* ever write

. . . because it could open the door to a lifetime job in a wonderful company

If you're an Electrical Engineer, with a high degree of skill and imagination in any of the twenty-odd fields listed right, we believe we can offer you the most promising opportunity in America.

Since 1940, Stromberg-Carlson's volume has increased *sixteen times*. In 1955, we became a division of the headline-making General Dynamics Corporation. Our future is as unlimited as humans can promise themselves—and *you* could well grow with us.

We are not looking for job-hoppers—but for men now stymied either by the limitations of a little company or the complexity of a giant. In any of the job classifications listed here, you'll find satisfaction and opportunity.

And you'll like Rochester—well-known for its grand schools, handsome residential sections and wide entertainment, vacation and cultural facilities. This firm's employee relations (including a liberal bonus plan) make it one of the state's preferred industries.

Write *today*—for an assured tomorrow!

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- Countermeasures
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- Digital Techniques
- Electro-mechanical Design
- Electronic Carillons
- Electronic Switching
- Infrared
- Intercom Systems
- Laboratory and Test Engineering
- Loudspeaker
- Magnetic Tape Recorders
- Microwave, communication
- Navigational Systems
- Radar
- Telephone Switching Technique
- Transistor Engineering
- Voice communication
- Writers—Bid Proposal
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Send your letter to Mr. Howard L. Foote

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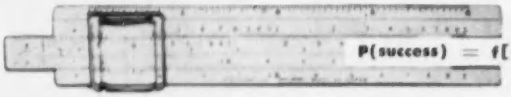
Airborne weapons systems have been added to the list of applications for Raytheon's hydraulic control systems. The recent expansion of our engineering facilities makes it possible to offer unusual opportunities to experienced creative engineers.
Beginning salary range—$6000 to $10,000

A brief resume form and a copy of this brochure describing our new laboratory may be obtained by writing to Mr. Robert E. Doherty.

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there's no **IF** *in YOUR professional future*
IF *you join an engineering team where*

THERE IS "GROUND FLOOR" OPPORTUNITY TO PROGRESS WITH A RAPIDLY-GROWING COMPANY

- *the educational level is unusually high, and you are associated with outstanding men who help you grow*
- *all work is challenging and stimulating*

YOU'LL
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- advance in position, prestige and income
- find your scientific assignments rewarding and satisfying.

Litton Industries of Beverly Hills, California, has openings on such an engineering team for seasoned engineers of proven creative ability. These positions offer exceptional engineering opportunities in *military, industrial* and *commercial electronics.*

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SYSTEMS ENGINEERING • VERY WIDE BAND AMPLIFIER TECHNIQUES • INERTIAL GUIDANCE
DIGITAL COMPUTERS AND CONTROLS • PRECISION COMPONENTS
SERVOMECHANISMS • ADVANCED CIRCUITRY

Men who have demonstrated the capacity for genuine creative work, are invited to write in confidence to the Personnel Manager, Electronic Equipment Division.

LITTON INDUSTRIES
336 NORTH FOOTHILL ROAD • BEVERLY HILLS, CALIFORNIA

To EMPLOYERS who advertise for MEN:

When there are many applicants for a single position it frequently happens that the only letters acknowledged are those of the most promising candidates. Others may not receive any indication that their letters have even been received by a prospective employer much less given consideration. These men often become discouraged, will not respond to future advertisements, and sometimes question their bona fide character.

Every advertisement printed in the Employment Opportunities Section is duly authorized.

It will help to keep our readers interested in this advertising if you will acknowledge every application received, even if you merely return the letters of unsuccessful applicants with, "Position filled, thank you" written or stamped on them. If you don't care to reveal your identity, mail them in plain envelopes.

We suggest this in a spirit of cooperation between employers and the men replying to positions Vacant advertisements.

★

"Put yourself in the other fellow's place"

★

Classified Advertising Division

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EXecutive 3-1230

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Photo-cell control systems, test equipment, custom electronic and magnetic amplifiers and power supplies, analog and digital circuitry and applications
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Specialized Control Systems
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HYDRAULIC - MECHANICAL
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Glen Cove 4-7300

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Comprehensive Control Engineering Services
Systems analysis and design of automatic controls and instrumentation for atomic energy . . . chemical plants . . . . petroleum refineries . . . . steel plants . . . . test facilities . . . . and other process industries.
915 Olive Street St. Louis 1, Missouri

CONSULTANTS

When you are represented in the PROFESSIONAL SERVICES SECTION of CONTROL ENGINEERING, you are contacting the executives who are responsible for calling in the experts.

For further information on how to reach these executives, write:

Professional Services Section
Control Engineering
330 W. 42nd Street,
New York 36, N. Y.

DEVELOPMENT ENGINEERS

Honeywell's Aeronautical Division is one of several Honeywell Divisions specializing in automatic controls. At Aero the main specialties are guidance and automatic flight control of missiles and aircraft, airborne instrumentation, airborne servomechanism components and jet engine controls.

■ Top development positions are open for aeronautical, mechanical and electrical engineers. This means complete design and development responsibility for components and systems in the field of autopilots, fuel measurement systems, inertial guidance systems, vertical and rate gyros, stabilization platforms, and many others.

■ As a design engineer you will provide technical direction for draftsmen, technicians, model makers and evaluation engineers essential to the project. An engineering degree or its equivalent plus practical experience with related or similar equipment is required.

CONSIDER THESE ADVANTAGES

■ Minneapolis, the city of lakes and parks, offers you metropolitan living in a suburban atmosphere. No commuting.

■ Your travel and family moving expenses paid.

■ Salaries, insurance-pension programs, plant and technical facilities are all first-rate.

■ Honeywell, leader in control systems, manufacturers of over 10,000 different products, offers unusual diversification and variety. A sound growth company, continually expanding, it offers permanent opportunity to you.

WRITE TO US

If you are interested in a career at Honeywell, call collect or send your resume to Bruce Wood, Dept. CE-5-98, Aeronautical Division, 2600 Ridgway Road, Minneapolis 13.

MINNEAPOLIS **Honeywell**

First in Controls

LIQUID ROCKET ENGINE DIVISION

AEROJET-GENERAL CORPORATION

has OPPORTUNITY for

SENIOR ENGINEER

as HEAD of

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This man will exercise primary responsibility for all controls system analysis within the Division. He will be given freedom to build up his own staff. Top level experience in turbojet, turbopump, ramjet or rocket engine controls is required. D.Sc preferred, major in servo theory.

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A few openings have developed in our organization for well qualified engineers who can participate in, and lead, in these areas:

- Analysis and development of controls systems and components
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Mature engineering judgment is essential and at least 3 to 5 years' experience in controls systems, servo-mechanisms and mechanical servos, with emphasis on the latter, and in some cases, proven ability in supervision.

These are not typical engineering positions. The work is of an advanced nature and opportunities for promotion are clearly outlined. The starting salary range of approximately $7,500 to $12,000 indicates a desirable economic level in the community and is coupled with many additional benefits.

The location in the Northeast is fine for family living. The operation offers stability in its product appeal to both commercial and military markets.

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P 1424 CONTROL ENGINEERING
330 W. 42 St., New York 36, N. Y.

$ SALES REPS. WANTED
For Complete Line of Telemetering, Control and Telegraph Terminals
We seek a few experienced sales engineering reps. to serve customers & call on prospects in Northwest, Southwest & South.
RADIO FREQUENCY LABORATORIES, Inc.
BOONTON, NEW JERSEY

NEED ENGINEERS?
An employment advertisement in this EMPLOYMENT OPPORTUNITIES section will help you find the engineers you need. It's an inexpensive, time saving method of selecting competent personnel for every engineering job in the control engineering field. The selective circulation of CONTROL ENGINEERING offers you an opportunity to choose the best qualified men available.

Your inquiry will have Special value . . .

If you mention this magazine, when writing advertisers. Naturally the publisher will appreciate it . . . but, more important, it will identify you as one of the men the advertiser wants to reach with this message . . . and help to make possible enlarged future service to you as a reader.

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When you are in need of specialized men for specialized jobs, contact them through a *classified ad* in a McGraw-Hill Publication.

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ELECTRICAL MERCHANDISING
ELECTRICAL WHOLESALING
ELECTRICAL WORLD
ELECTRONICS
ENGINEERING AND MINING JOURNAL
ENGINEERING NEWS-RECORD
FACTORY MANAGEMENT AND MAINTENANCE
FLEET OWNER
FOOD ENGINEERING
NATIONAL PETROLEUM NEWS
NUCLEONICS
PETROLEUM PROCESSING
POWER
PRODUCT ENGINEERING
TEXTILE WORLD

THE MEN YOU NEED ARE THE MEN WHO READ THE

McGRAW-HILL PUBLICATIONS
330 West 42nd St.,
New York 36, N. Y.

CONTROL TRANSMITTER

(CLASSIFIED ADVERTISING)
SALES ● BUSINESS
EQUIPMENT (Used or Resale)
"OPPORTUNITIES"

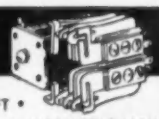
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(Not available for equipment advertising)
$1.80 per line, minimum 3 lines. To figure advance payment count 5 average words to a line.

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The advertising rate is $17.80 per inch for all advertising appearing on other than contract basis. Contract rates quoted on request.

RELAYS



MINIATURE AIRCRAFT • TELEPHONE TYPE • HERMETICALLY SEALED • SENSITROLS • STEPPING SWITCHES • GUARDIAN • KURMAN • ALLIED • SIGMA • LEACH *and many others.*

LARGEST STOCK OF RELAYS IN THE WORLD
PRODUCTION QUANTITIES IN STOCK
Send for our latest bulletin C

Universal general corp.
324 CANAL ST., N.Y.C., 13, N.Y. WAlker 5-9642

MAY WE HAVE YOUR ATTENTION?

The "CONTROL TRANSMITTER" serves as an active market place for buying and selling used and surplus elements and components of control systems. It will be consulted regularly by prospective buyers of such equipment offered by individual plants or dealers.

If you have used or surplus elements and components of control systems lying around idle in your plant, you can help other readers of the "CONTROL TRANSMITTER" who need such equipment by bringing it to their attention.

You may find bargains in hard-to-get components through the dealers advertising in this section. Make the reading of "CONTROL TRANSMITTER" a monthly habit.

GM AIRCRAFT POWER

New Opportunities for **ENGINEERS**

ALLISON DIVISION

General Motors Corporation

is spending

$75,000,000

on a long range expansion program in **ENGINEERING RESEARCH and DEVELOPMENT FACILITIES**

Completion of the program will give Allison one of the world's most complete, best-equipped centers for the development of new, high performance turbo-prop and turbo-jet aircraft engines.

This extensive expansion program—financed by General Motors—creates an immediate need for a 40% increase in engineering personnel.

Also, the Allison Model 501 turbo-prop engine and Aeroproducts propeller have been selected by leading airlines to power the passenger planes for tomorrow's turbo-prop transport travel creating additional opportunities for you in the commercial field.

Experience in the aircraft industry isn't always necessary. If you are an engineering graduate, we'd like to talk to you. There's everything to gain—nothing to lose.

Here are some of the advantages offered by Allison: stability of a growing organization . . . . security . . . . advanced educational facilities opportunity for rapid advancement . . . . excellent working conditions with the most modern facilities in industry . . . . and association with top level technical men in the industry. If you've had experience or training, in any of the following fields, we'd like to talk to you about your future at Allison in aircraft engines and Aeroproducts propellers:



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Also immediate openings for:

PHYSICISTS, NUCLEAR PHYSICISTS and ENGINEERS with ELECTRONICS EXPERIENCE.

Write direct to Salaried Personnel, Dept. CE, telling us about yourself . . . . your qualifications . . . . your academic and work experience background.

ALLISON **Division General Motors Corporation**
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Design, development and production — high power TURBINE ENGINES for modern aircraft . . . . Aeroproducts PROPELLERS, ACTUATORS and DIESEL ENGINE STARTERS . . . . Heavy duty TRANSMISSIONS for Ordnance and Commercial vehicles . . . . DIESEL LOCOMOTIVE PARTS . . . . PRECISION BEARINGS for aircraft, Diesel locomotives and special application.

VHS* RELAY

(*Very High Sensitivity)



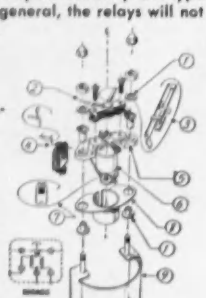


Model 266

Sample specs. are: 0.2 micro-amperes, (12,000 ohms coil) or, 0.1 millivolts, (5 ohms.)

• The VHS is a balanced armature, Alnico magnet type relay. It is internally shock-mounted and resistant to vibration. The screw-on cover is gasket sealed. It can be opened and resealed.

Connections: 9 pin octal style. Dimensions: 1¾ diameter x 2¼ long. Weight: 4 ounces. Sensitivity: Infinite variations from 0.2 Ua. to 10 Amp. or 0.1 Mv. to 500 volts, self contained. Higher volts or amps with external multipliers. A.C. rectifier types. Trip point accuracies to 1%. Differential 1%. The degree of resistance to shock and vibration primarily depends upon sensitivity and type of action wanted. In general, the relays will not be permanently damaged by shocks of 100 G's and vibrations up to 2,000 cps at 4 G's. The most sensitive relays may close their contacts under these conditions.



Contacts: SPST or SPDT, 5-25 Ma. D.C. Other ratings to ½ Amp. A.C. A locking coil gives high pressure and chatter free contact under shock and vibration.

Prices: $20-$80. Delivery 4 to 6 weeks. Assembly Products, Inc., Chesterland 22, Ohio.

Write for explanation of model

(West Coast: Desert Hot Springs 22, California. Phone 4-2468) Booth 507, Design Engineering Show, Philadelphia, May 14-17.



7—FAMILIAR FACES

7 Famous Features

TORK TIME SWITCHES EMBRACE ANY REPEATING TIME RANGE FROM SPLIT MINUTES TO WEEKS

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- Follow sun-time all year around.
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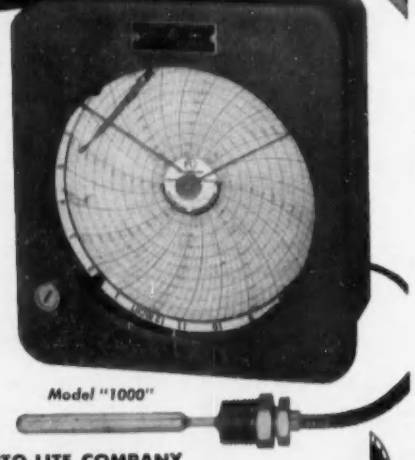
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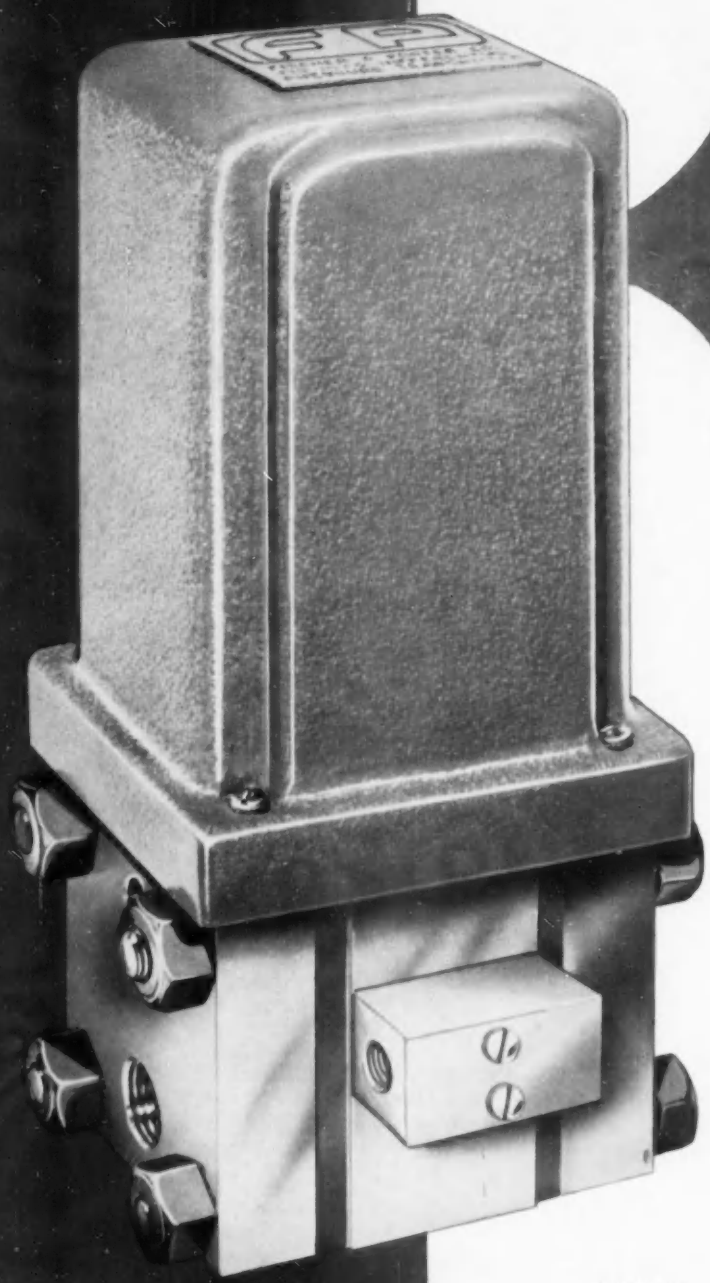
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